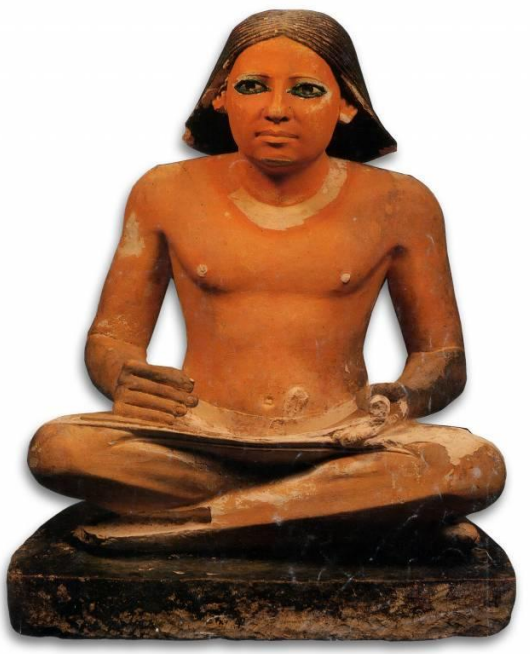
Musculoskeletal

Joints



Compiled by

Dr. M. Samy, MD

List of contents

- **Upper Limb:**
  - **Shoulder**
  - **Acromio-Clavicular Joint**
  - **Sterno-Clavicular Joint**
  - **Elbow**
  - **Wrist**
  - **Hand & Thumb**

- **Tempro-Mandibular Joint**

- **Lower Limb:**
  - **Hip**
  - **Knee**
  - **Ankle**
  - **Foot**

Shoulder Joint

❖ Anatomy

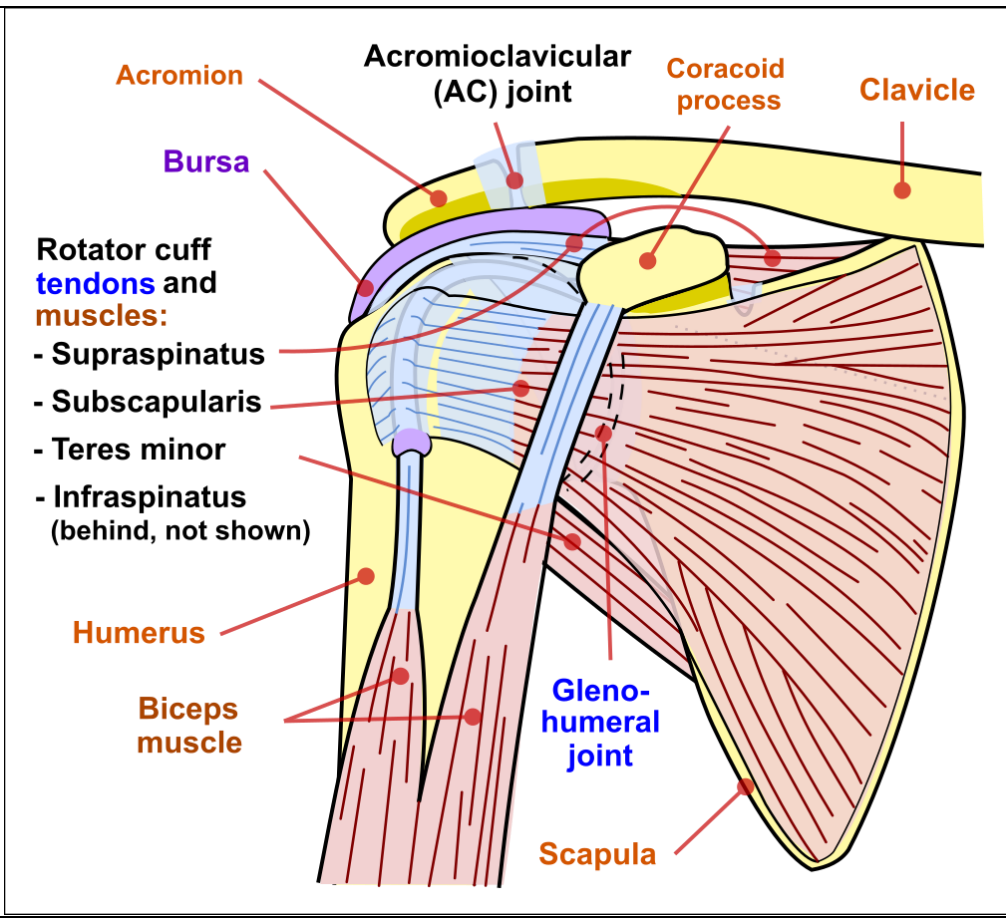
- It is a ball and socket joint that allows a great range of motion.

Shoulder joint is complex joint consists of:

- Gleno-humeral joint
- Acromio-clavicular joint
- Sterno-clavicular joint

The joint is reinforced by:

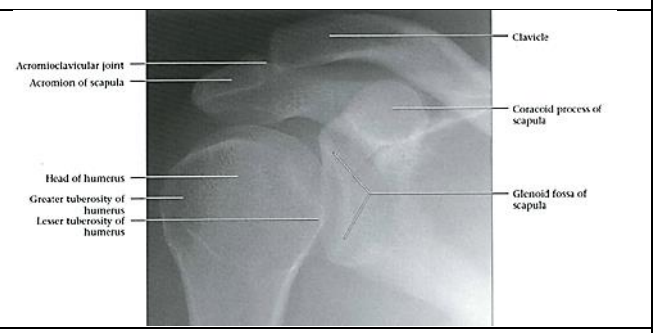
- **Rotator cuff tendons**
- **Joint capsule**
- **Glenoid labrum**
- **Gleno-humeral ligaments.**
- **Long head of biceps tendon**



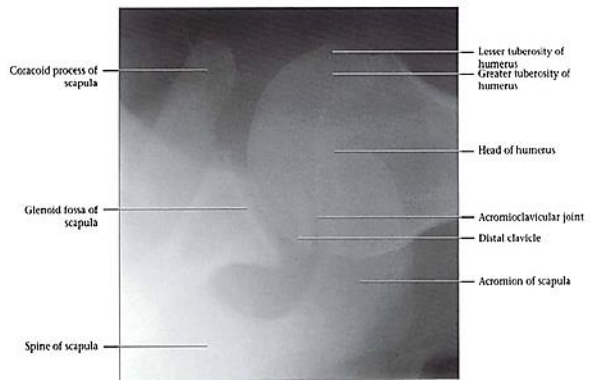
❖ X-RAY

AP – External Rotation

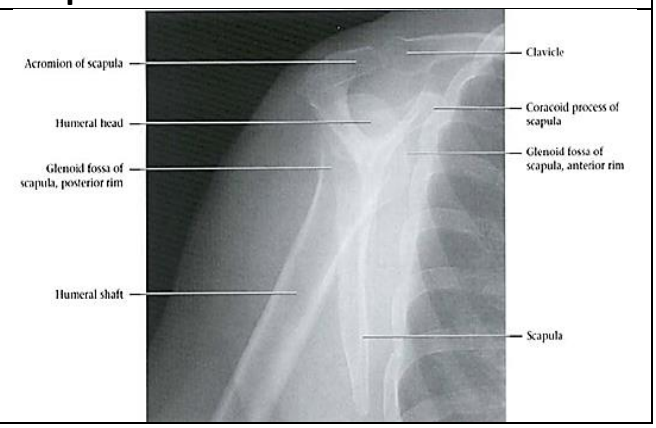
AP – Internal Rotation



Axillary View



Scapular Y VIEW



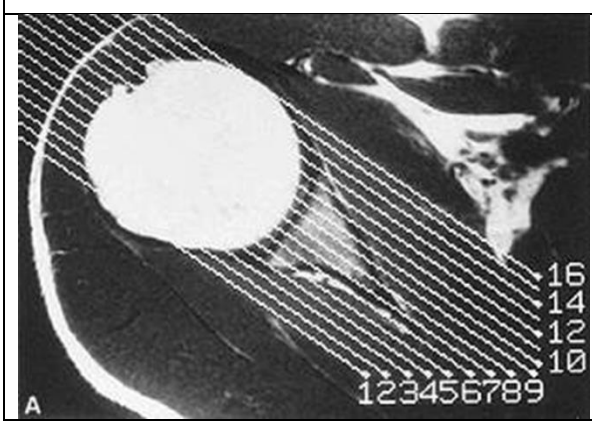
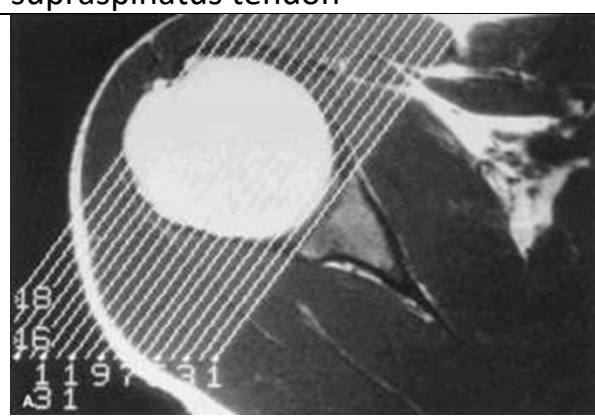
❖MRI Technique

Patient positioning

- Supine with the head directed towards the scanner bore.
- The arm is placed in neutral to slightly externally rotated.
- Surface coils

MRI protocol:

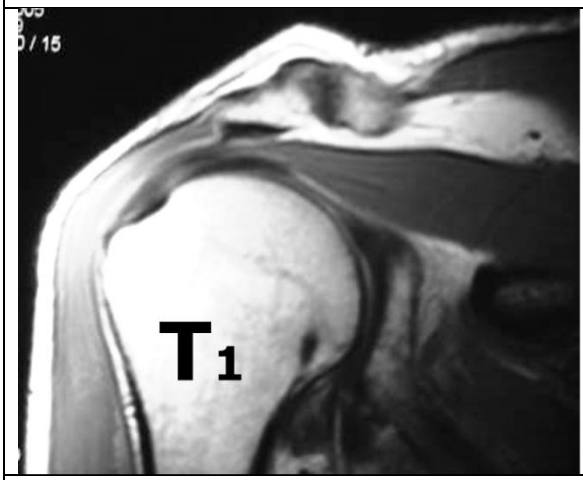
- Coronal Localizer
- Axial GRE or T2-WIs.
- Coronal oblique T1; T2 and T2/fat-suppressed.
- Sagittal oblique T2-WIs.

Coronal oblique	Sagittal oblique
images are obtained in a plane parallel to the supraspinatus tendon.	images are obtained in plane perpendicular to that of the supraspinatus tendon
	

❖ Rotator Cuff Tendons & Muscles

1) Supraspinatous Tendon

- Origin: Supraspinous fossa of the scapula
- Insertion: Greater humeral tubercle



2) Infraspinatus Tendon

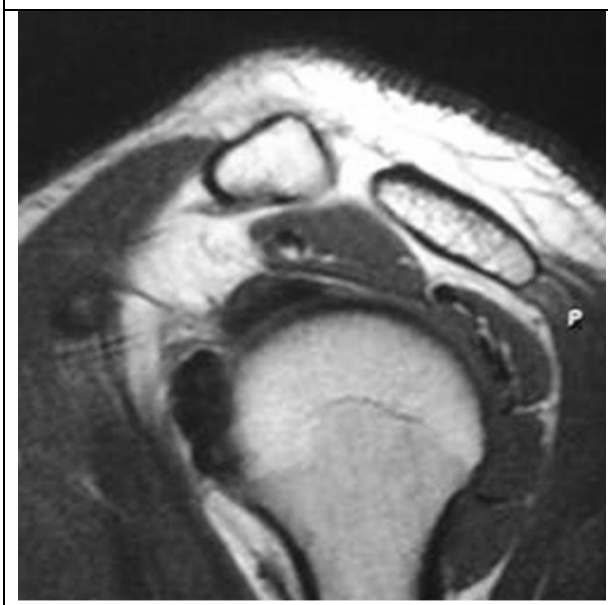
- Origin: Infraspinous fossa of the scapula
- Insertion: Greater humeral tubercle

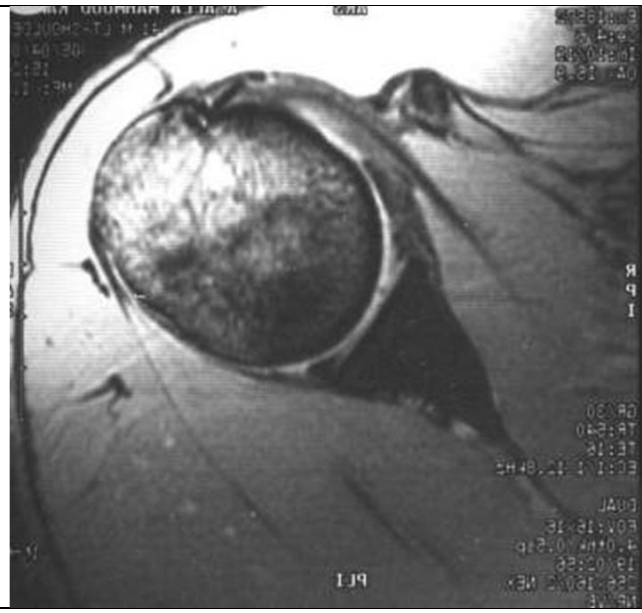
3) Teres Minor

- Origin: Inferolateral border of the scapula
- Insertion: Inferior facet on the greater tubercle

4) Subscapularis Tendon

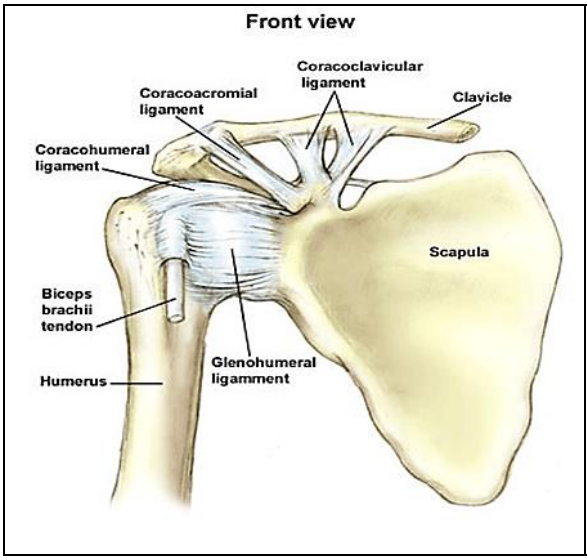
- Origin: subscapular fossa of the scapula
- Insertion: Lesser humeral tubercle

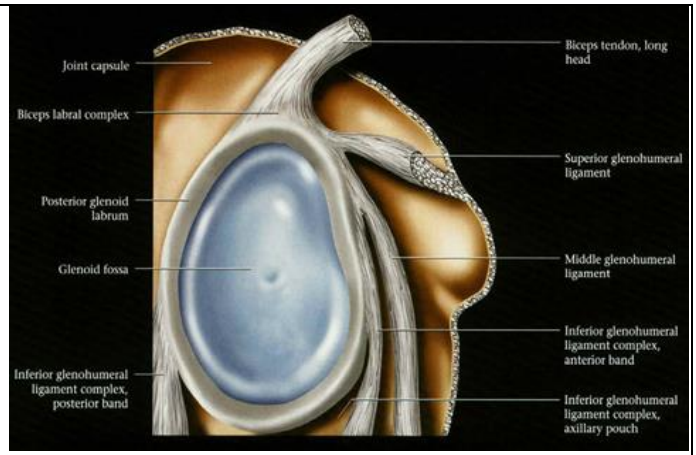




❖Ligaments

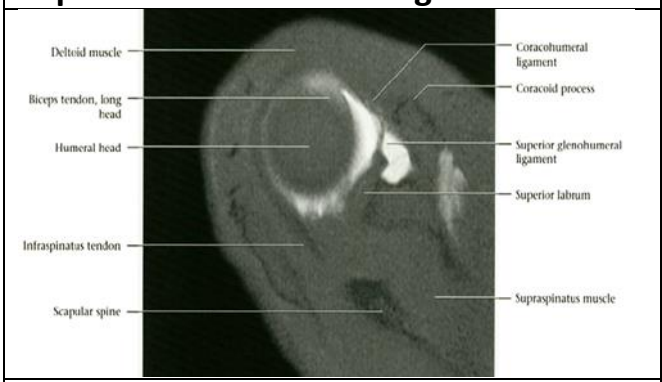
➢ Superior Acromioclavicular (AC) ➢ Inferior Acromioclavicular (AC) ➢ Coraco-acromial ➢ Coraco-clavicular ➢ Coraco-humeral (CH) ➢ Transverse humeral	➢ Superior glenohumeral ligament (SGHL) ➢ Middle glenohumeral ligament (MGHL) ➢ Inferior glenohumeral ligament (IGHL)



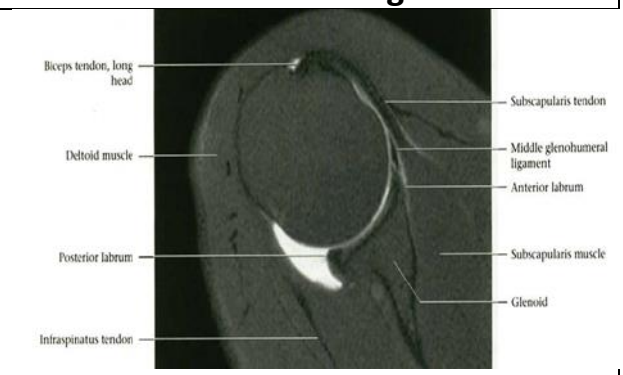


Axial T1 Fs MR Arthrogram

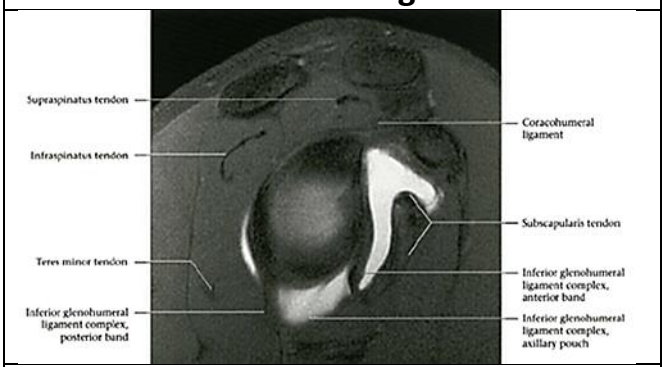
Superior Glenohumeral Ligament



Middle Glenohumeral Ligament



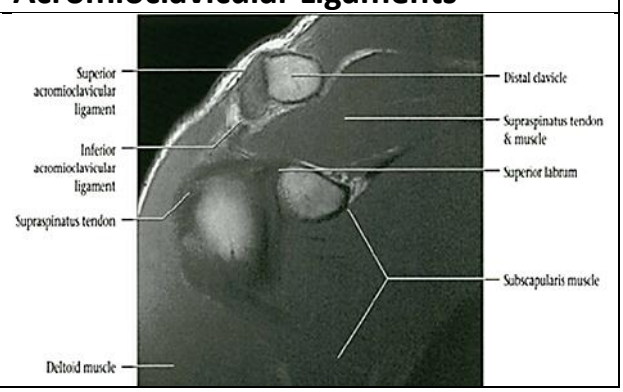
Inferior Glenohumeral Ligament



Coraco-Humeral Ligament

Coraco-clavicular Ligament

Acromioclavicular Ligaments

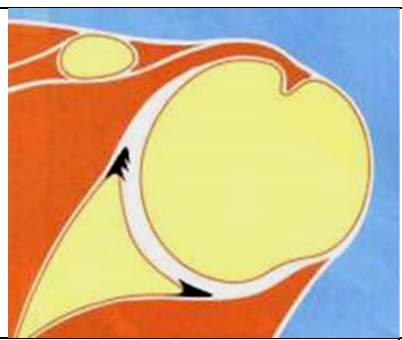


❖ Glenoid Labrum

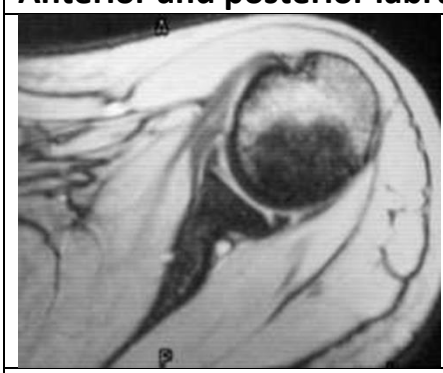
- Fibro-cartilaginous structure
- Low signal on t1 & T2
- Triangular shape
- Rounded, cleaved, notched variants.

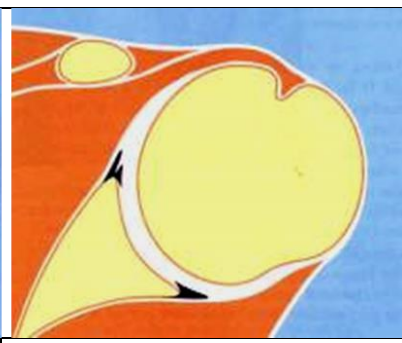
Portions of labrum described as positions on face of clock (either shoulder)

- ✓ **12:00: Superior**
- ✓ **3:00: Anterior**
- ✓ **6:00: Inferior**
- ✓ **9:00: Posterior**



Anterior and posterior labrum (axial)

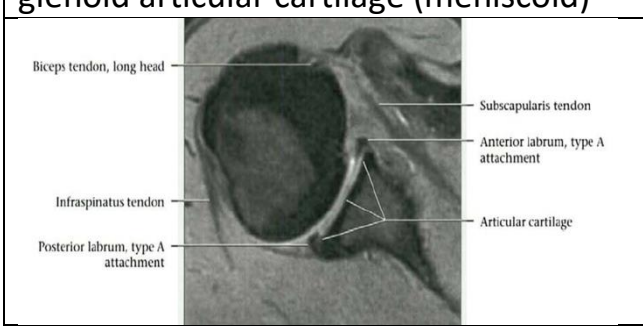




Inferior and superior labrum (coronal)

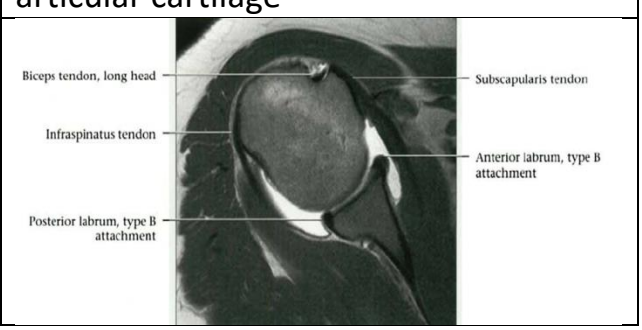
Type A Labral Attachment

Type A: Detached free edge overlying glenoid articular cartilage (meniscoid)



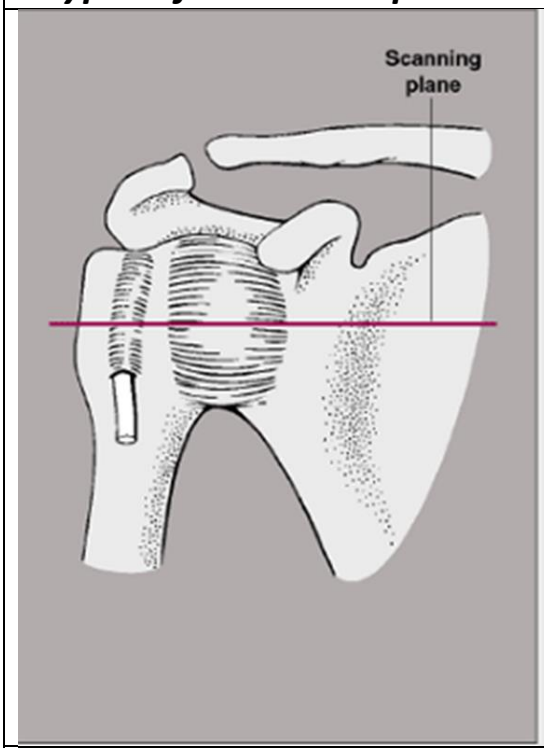
Type B Labral Attachment

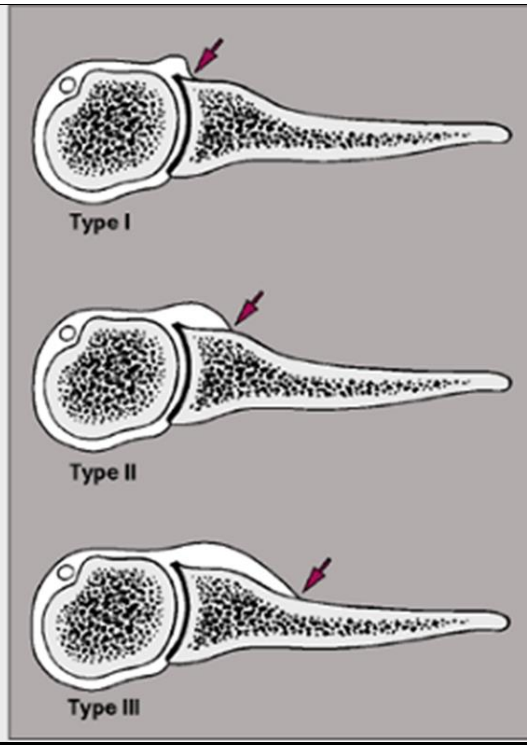
Type B: Adherent to the glenoid articular cartilage



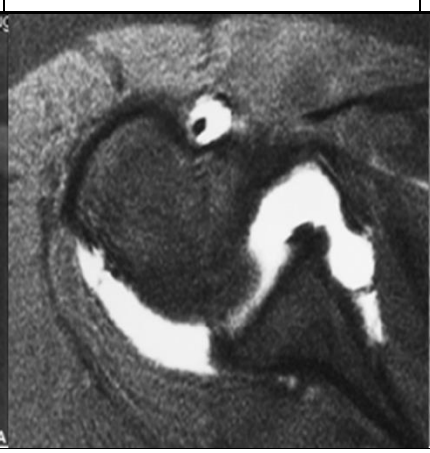
❖ Capsule Of Shoulder Joint

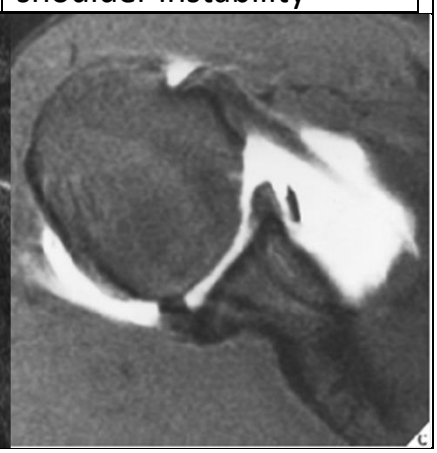
3 types of anterior capsular insertion to the scapula





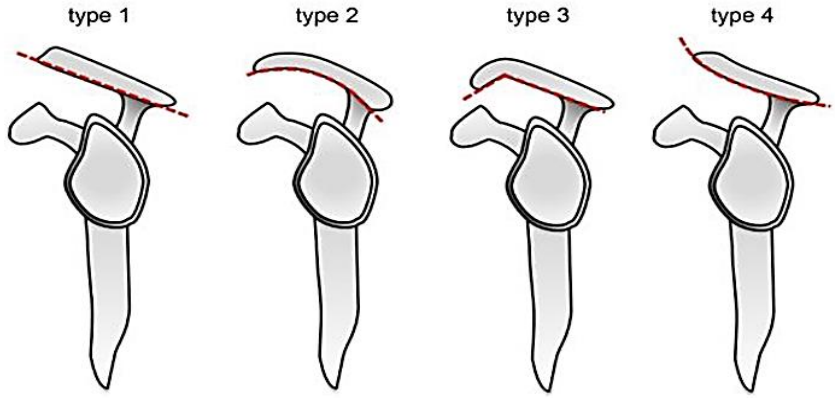
Type I	Type II	Type III
at or very near the labrum	just medial to the labrum, within 1 cm	more than 1 cm medial to the labrum
		Type III is associated with shoulder instability



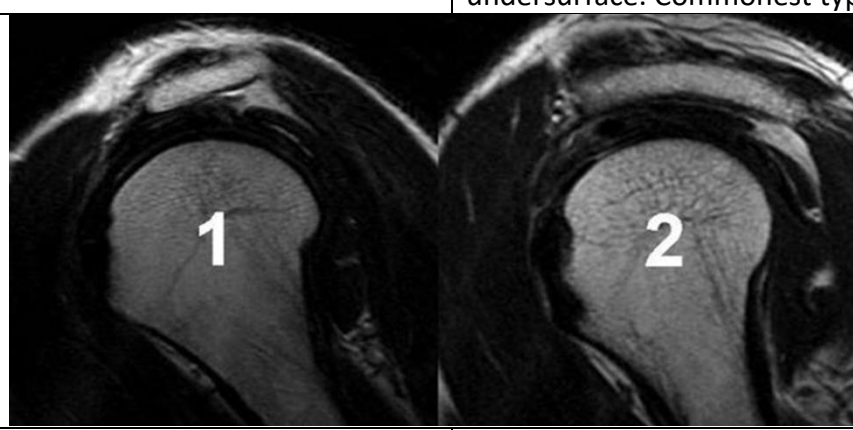


❖ Acromion Process

BIGLIANI Classification of Acromial Morphology

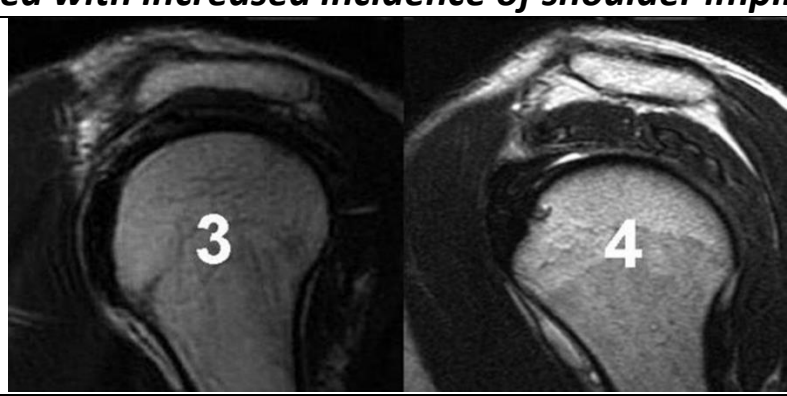


Type I: Flat inferiorly	**Type II: Curved**
	Parallel to the humeral head with convex undersurface. Commonest type



Type III = Hooked	**Type IV= Convex**
The most anterior portion of the acromion has a hooked shape	The undersurface is convex

Associated with increased incidence of shoulder impingement



Shoulder Dislocation

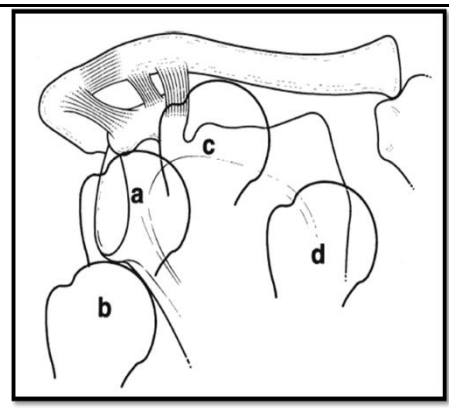
Anterior	95% of dislocations direct blow or fall on outstretched arm
Posterior	Due to electric shock or seizure Go often unnoticed
Inferior	Very uncommon also called luxatio erecta many complications: vascular, neurologic

I- Anterior Shoulder Dislocation

❖ **Most common type of shoulder dislocation.**

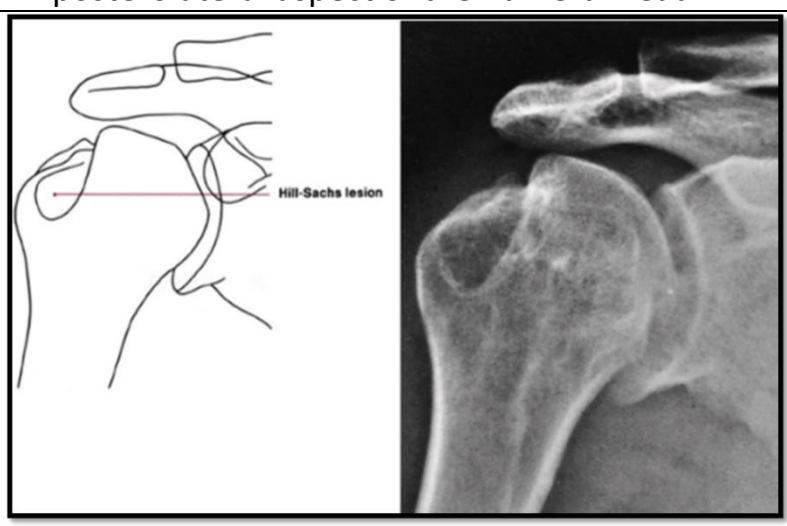
Position of the humeral head and types of anterior dislocation:.

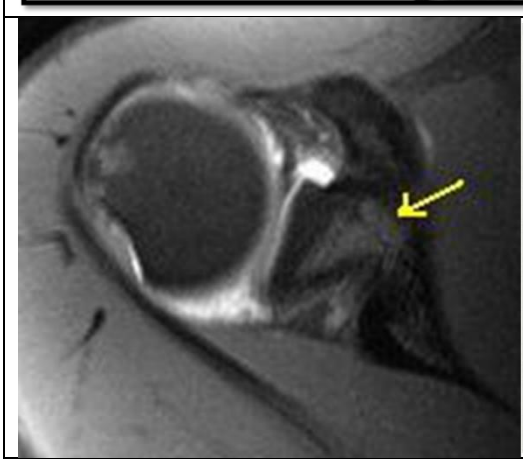
a) **Subcoracoid**
b) **Subglenoid**
c) **Subclavicular**
d) **Intrathoracic**

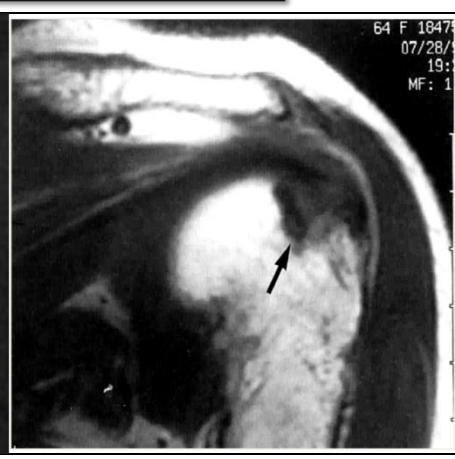


1) Hill-Sachs Lesion

- Anteroposterior view of the shoulder with the arm internally rotated demonstrates a “hatchet” defect, known as the Hill-Sachs lesion, on the posterolateral aspect of the humeral head.

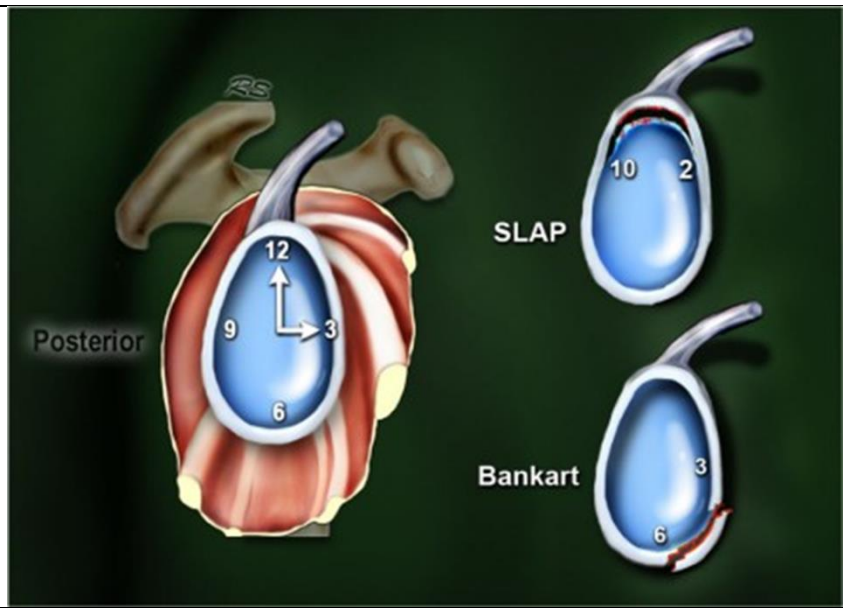


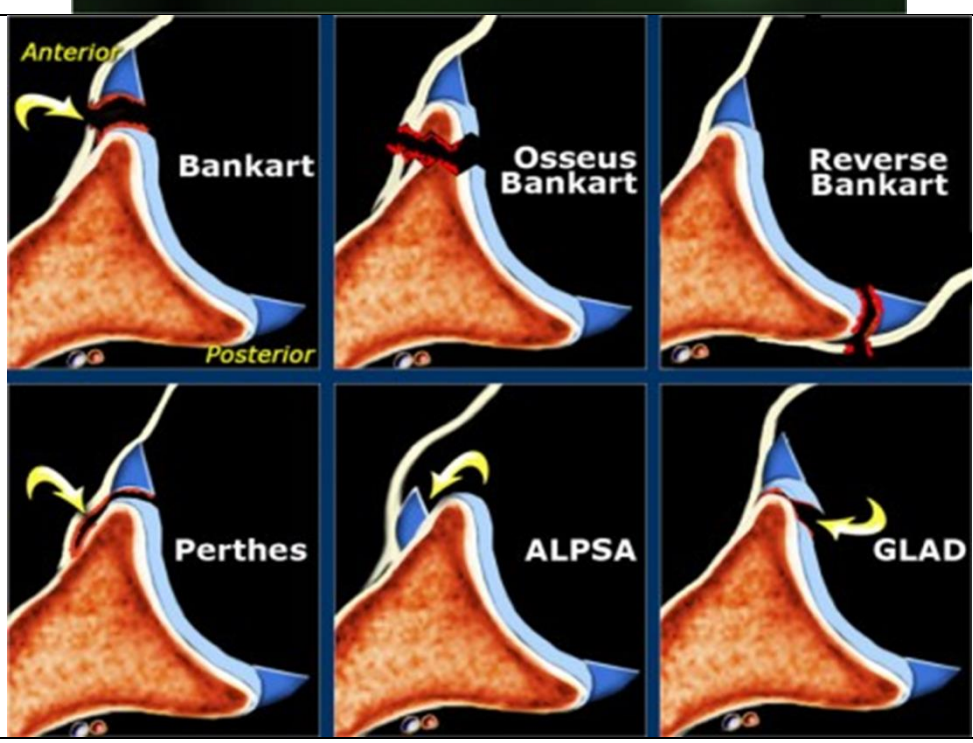




2) Anteroinferior Labroligamentous Injuries

- Bankart
- Bony Bankart
- ALPSA = Anterior Labral Periosteal Sleeve Avulsion
- Perthes
- GLAD = Glenolabral Articular Disruption
- HAGL / BHAGL





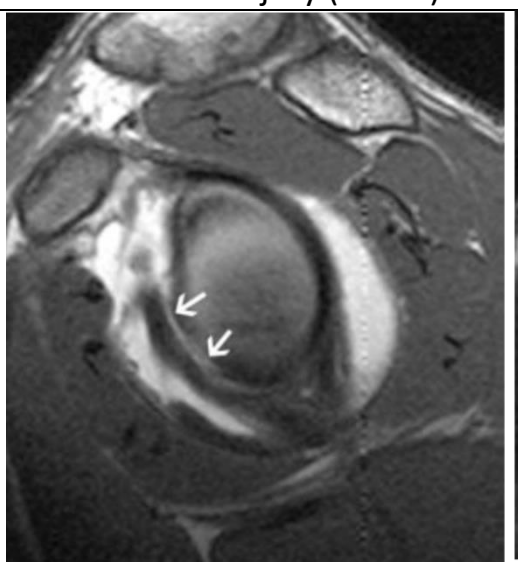
i) Bankart Lesion

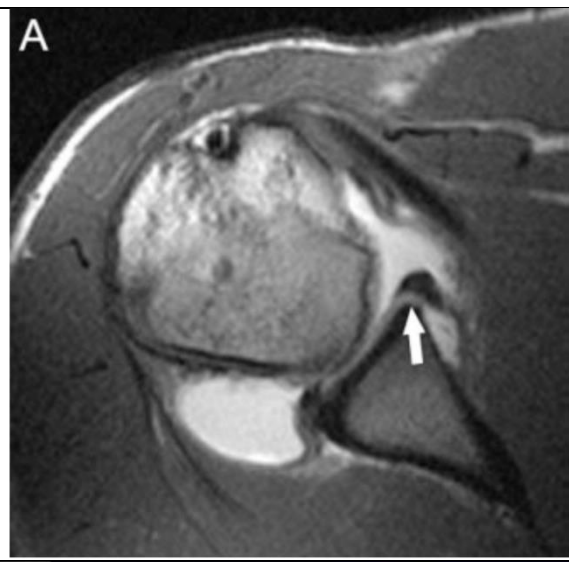
Conventional MRI:

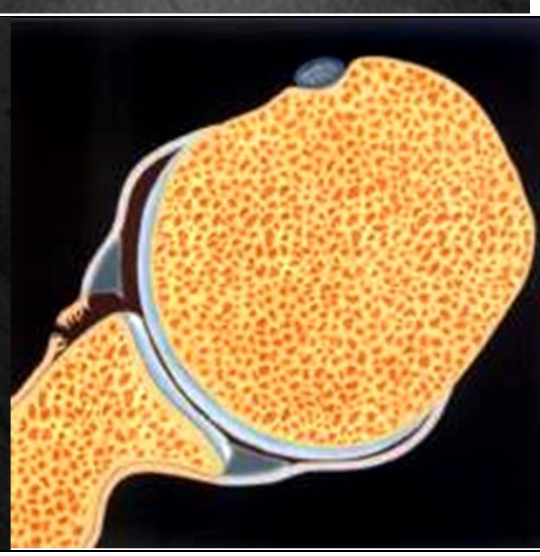
- Loss of the triangular shape
- Increased SI of the anteroinferior labrum

MR Arthogram:

Contrast medium interposition between the glenoid rim and the detached anteroinferior labral injury (arrow).

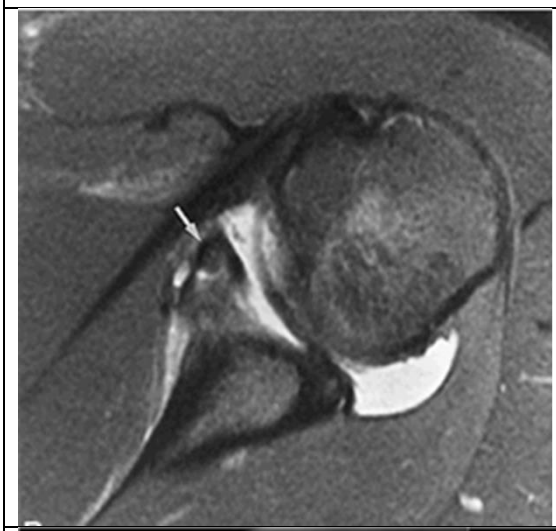


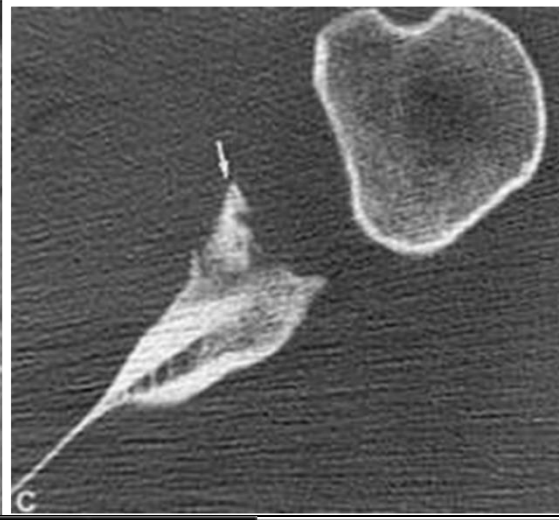


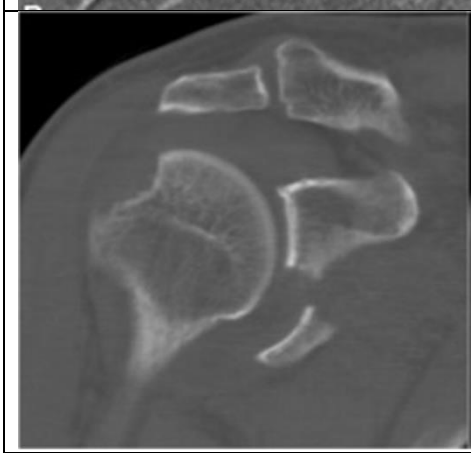


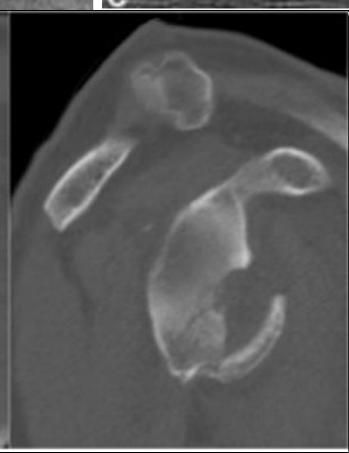
ii) Osseous Bankart

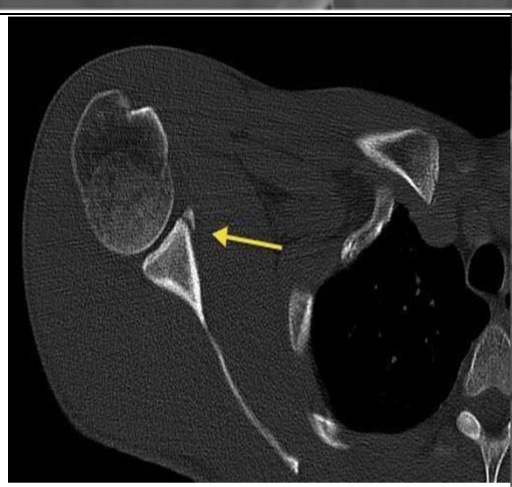
Avulsion of the anterior labrum + detachment of the inferior glenoid rim

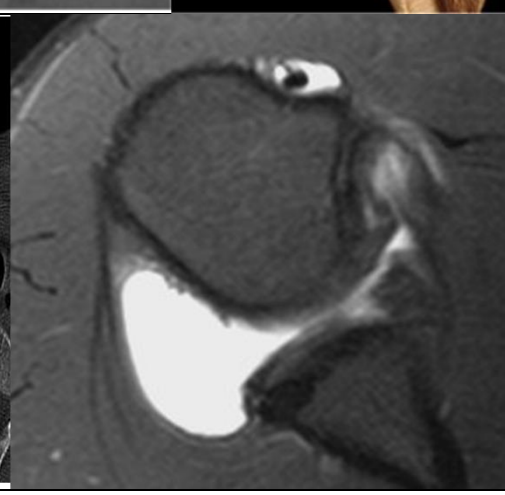






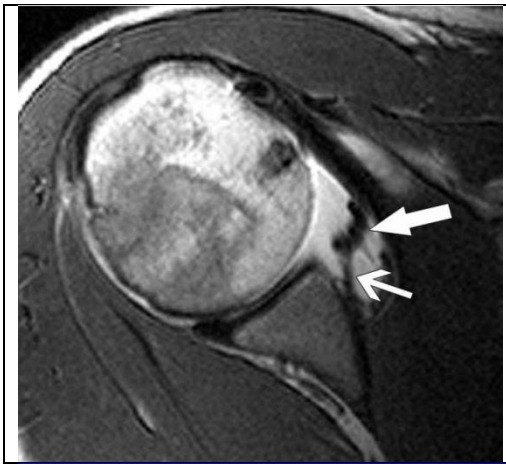


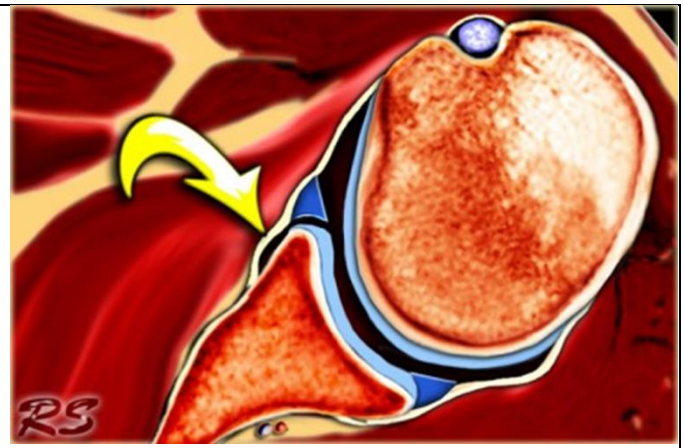


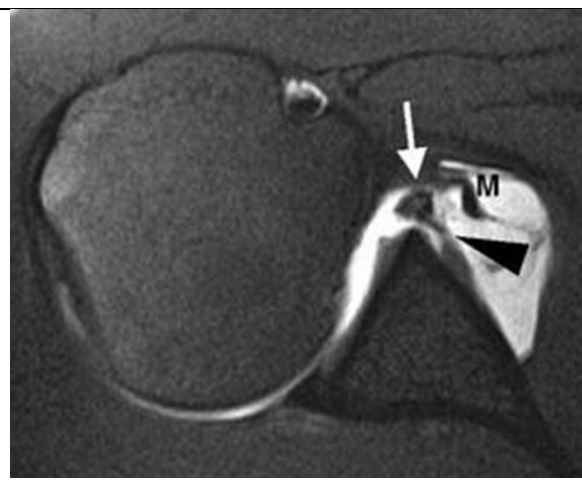


iii) Perthes Lesion

- Non-displaced or slight anterior displaced tear of the anteroinferior labrum.
- Medially stripped intact periosteum

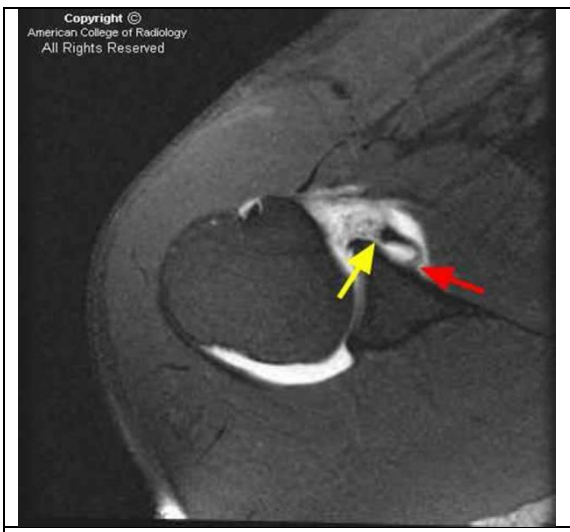




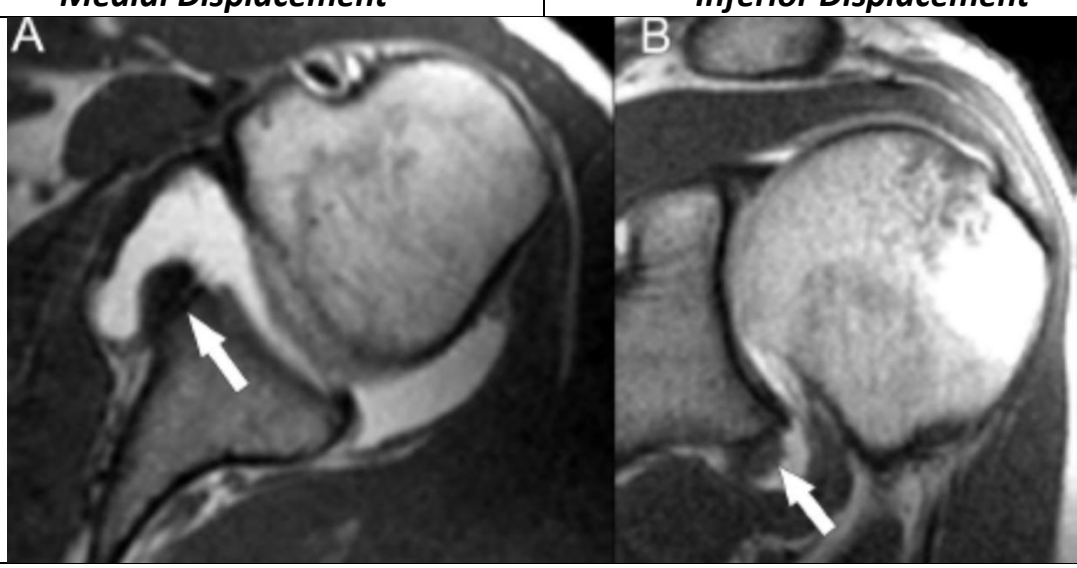


iv) ALPSA = Anterior Labroligamentous Periosteal Sleeve Avulsion

- Avulsion of the anterior labrum from the anterioinferior glenoid
- + Medially and inferiorly displaced labrum on the scapular neck
- + Labrum maintaining connection to glenoid via stripped intact periosteum.

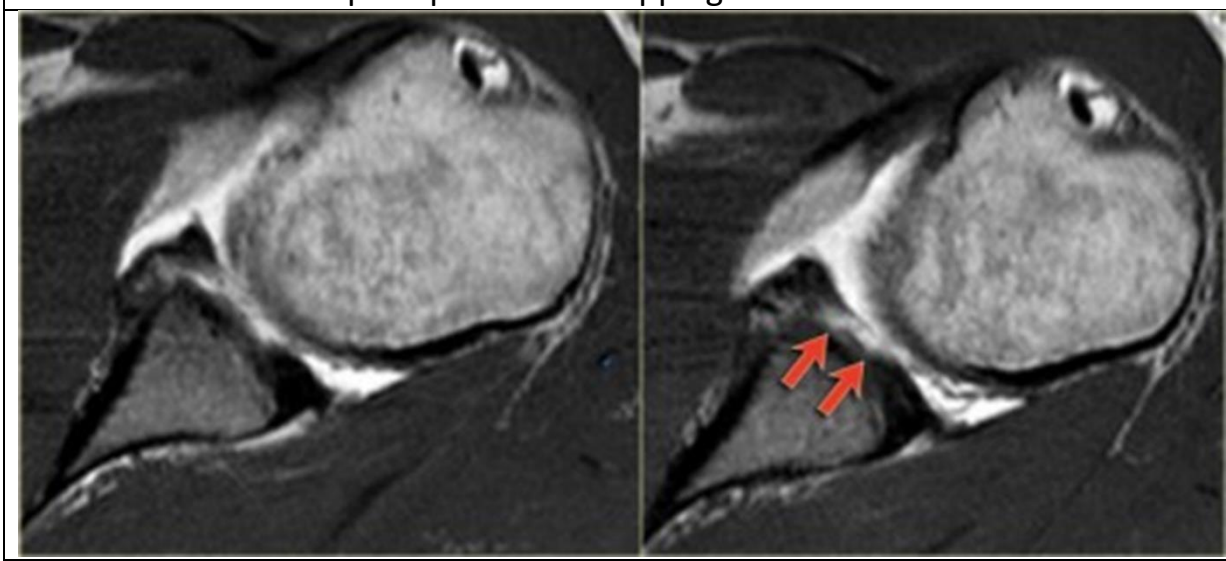


Medial Displacement | ***Inferior Displacement***



v) GLAD = GlenoLabral Articular Disruption

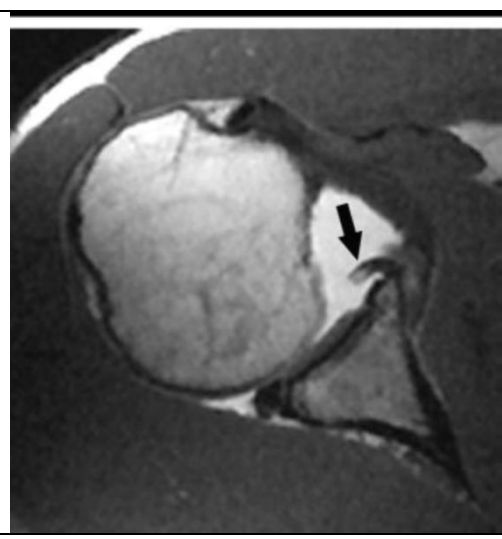
- Superficial tear of the anteroinferior labrum
- + adjacent articular cartilage injury.
- + No associated capsuloperiosteal stripping



MR Arthogram:

Full-thickness chondral lesion +

Injury of the anteroinferior labroligamentous complex (arrow).



vi) HAGL/BHAGL = Humeral Avulsion of the Inferior Glenohumeral Ligament (IGHL)

- HAGL/BHAGL should be sought in the presence of traumatic anterior instability when a Bankart lesion is not present.
- Humeral avulsion of the anterior band of the IGHL (HAGL) is an uncommon but important injury occurring in 7.5% of cases of anterior glenohumeral instability.
- Bony humeral avulsion of the inferior glenohumeral ligament (BHAGL) is a less common variant (20% of cases) and presents with anterior instability or impingement.
- Detachment of both the humeral and glenoid attachment of the inferior glenohumeral ligament can also occur and is referred to as the "floating" AIGHL.

MRI Findings:

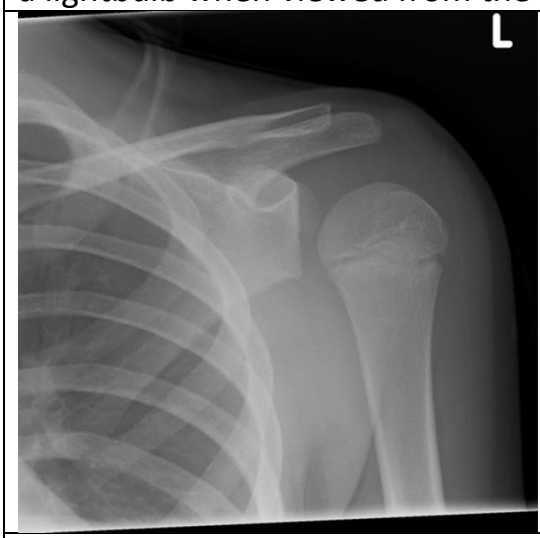
- Extravasation of contrast through the capsular avulsion
- J-shaped avulsed IGHL ("J" sign),
- irregularity of the humeral capsular attachment, disruption of the normal continuous decreased signal intensity line of the capsule,
- Edema/hemorrhage anterior and inferior to the shoulder joint.
- Arthrographic findings include extravasation of contrast into the soft tissues anterior and inferior to the joint.

Normal	HAGL

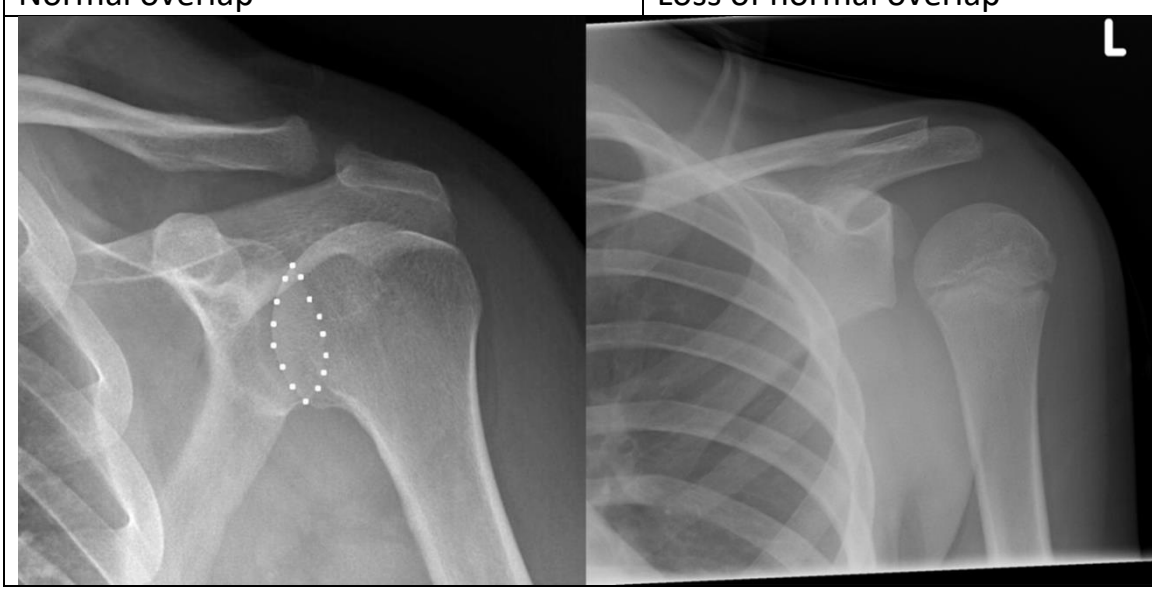
II- Posterior Shoulder Dislocation

- Posterior shoulder dislocation is far less common than anterior shoulder dislocation.

❖ Signs in AP view

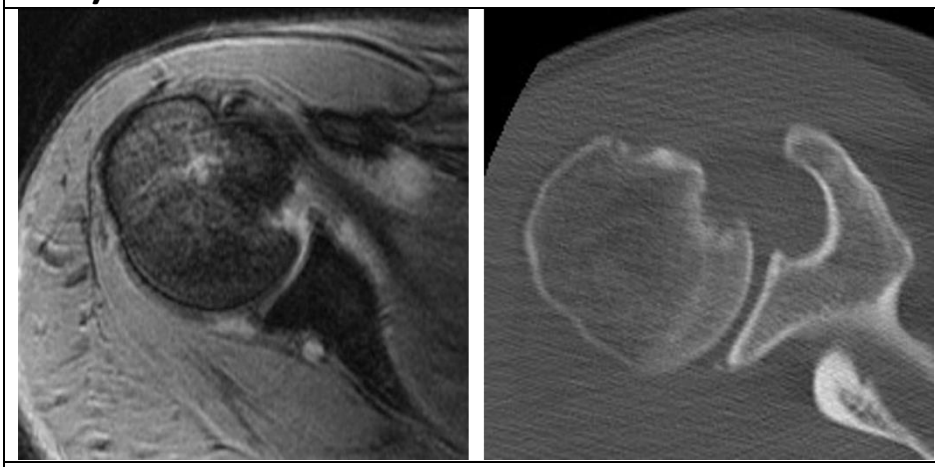
1) Lightbulb Sign	2) Trough Line Sign
The humeral head contour projects like a lightbulb when viewed from the front.	Two nearly parallel lines in the superomedial aspect of humeral head
	

3) Loss Of Normal Half Moon Overlap Sign

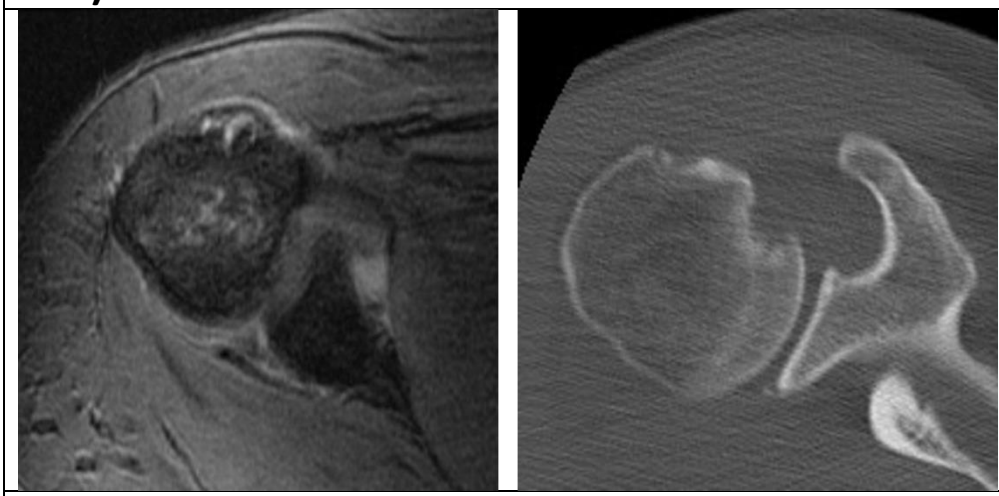
Normal overlap	Loss of normal overlap
	

❖ **MRI Imaging Findings:**

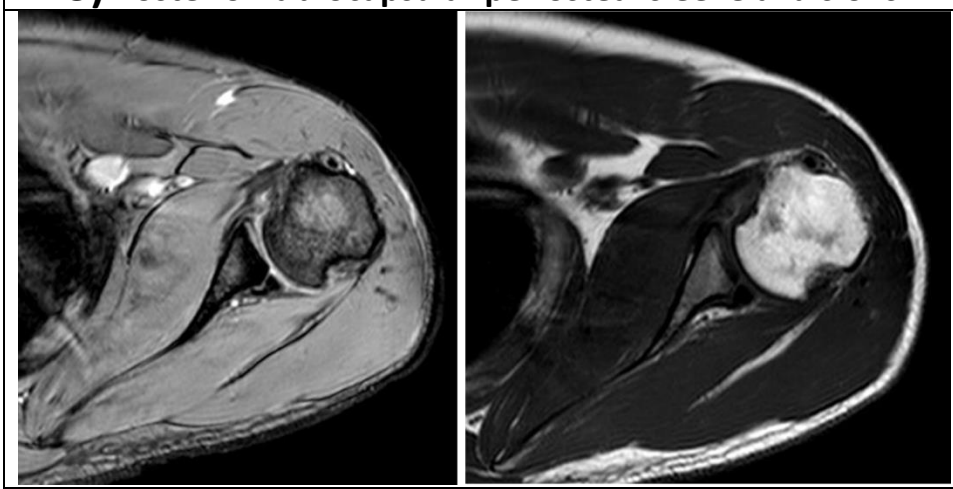
1) Reverse Hill-Sachs lesion



2) Reverse Bankart lesion



3) Posterior labrocapsular periosteal sleeve avulsions = POLPSA lesion

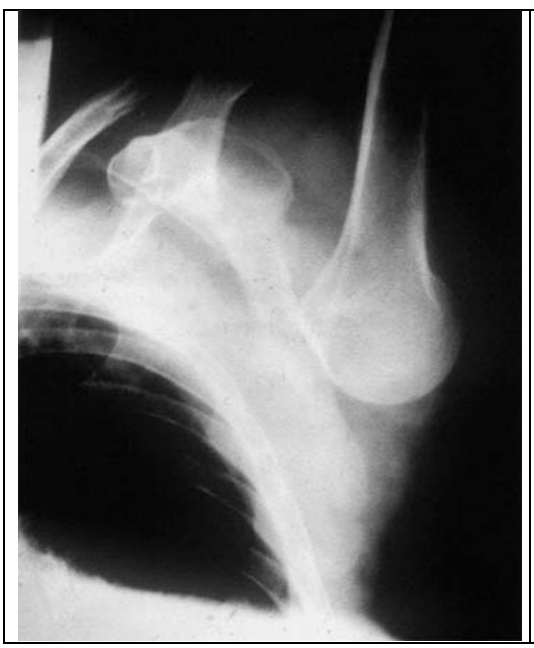


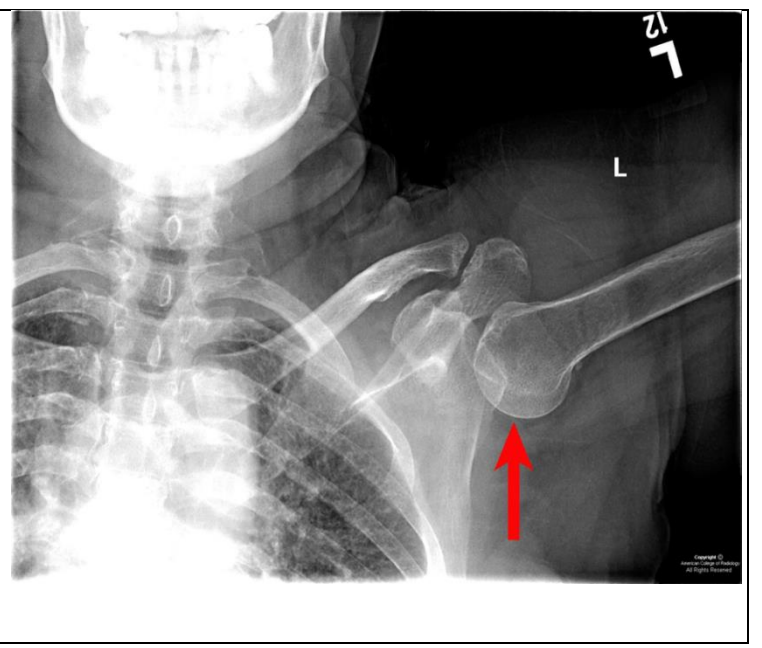
III- Inferior Shoulder Dislocation = Luxatio Erecta

- is the least common form of shoulder dislocation.
- The arm appears to be permanently held upward, in fixed abduction.
- The patient will often present with their hand placed on the head or near it.
- The humeral head is situated inferiorly below the glenoid

Common MRI Findings:

- Rotator cuff tears
- Injuries to the glenoid labrum
- Injuries to both the anterior and posterior band of the inferior glenohumeral ligament (IGHL)
- Bone bruises or impaction fractures (Hill-sachs lesion) at the superolateral aspect of the humeral head





Shoulder Impingement

I.	**Subacromial impingement (most common)**
II.	**Subcoracoid impingement (affects subscapularis)**
III.	**Posterosuperior / Internal impingement (involves infraspinatus)**

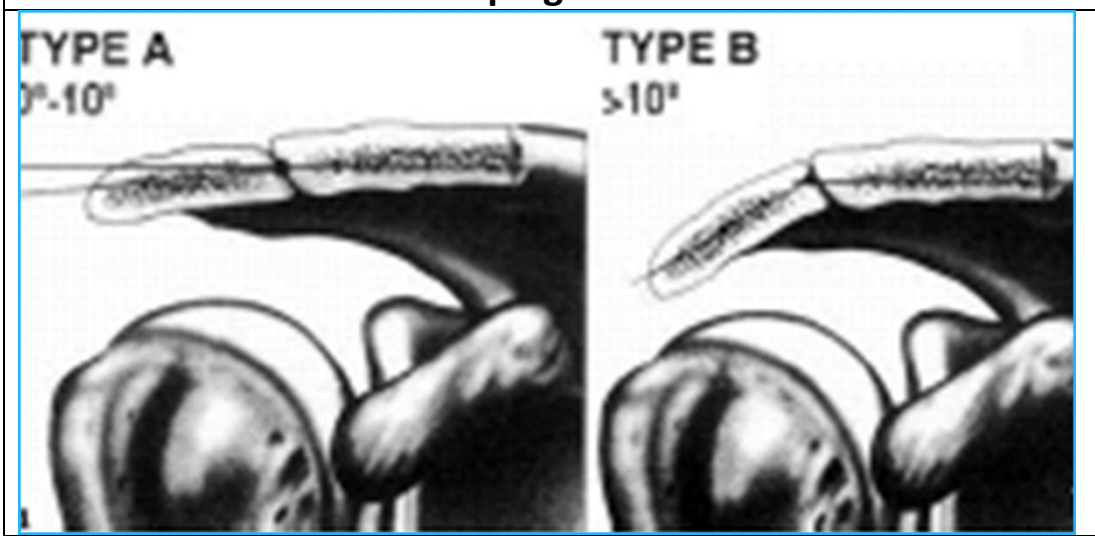
I- Subacromial Impingement

Most common type of Shoulder impingement

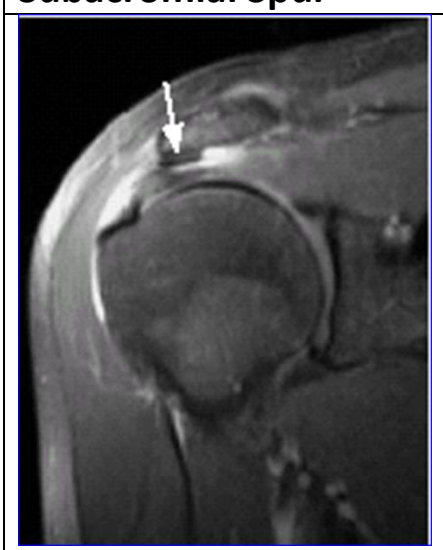
a) Osseous abormalities that lead to impingement include:

- Acromion:
  - Subacromial spurs.
  - Anterior hooking
  - Lateral Downsloping
  - Os acromiale.
- AC joint degeneration.

Lateral Acromion Downsloping

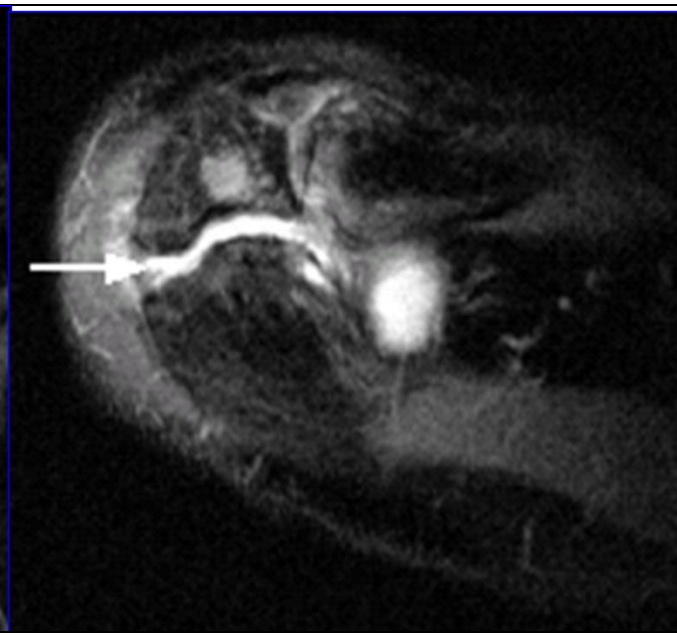


Subacromial Spur

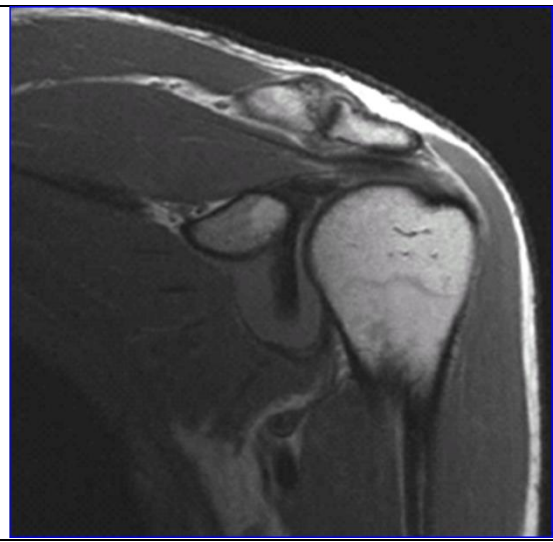


Anteriorly hooked Acromion

Os Acromiale



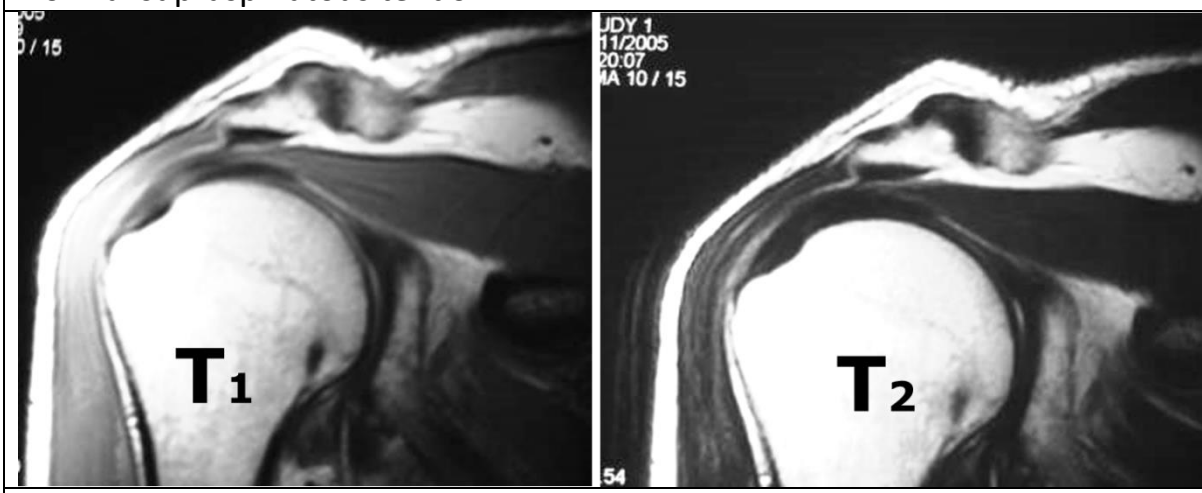
Acromioclavicular Joint degenerative Osteoarthritis



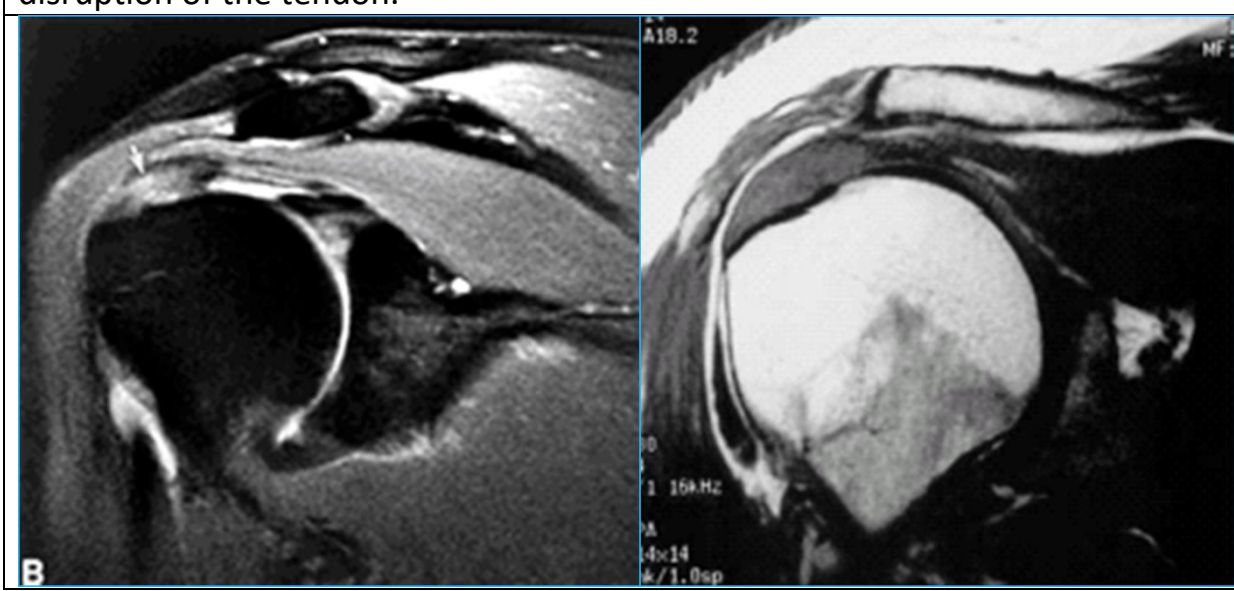
b) Soft tissue abnormalities associated with impingement:

- Rotator cuff tendon tear.
  - Tendinosis / Tendinopathy
  - Partial thickness tear
  - Full thickness tear
- Subacromial / Subdeltoid bursitis.
- Thickened cocaro-acromial ligament.

Normal supraspinatous tendon:

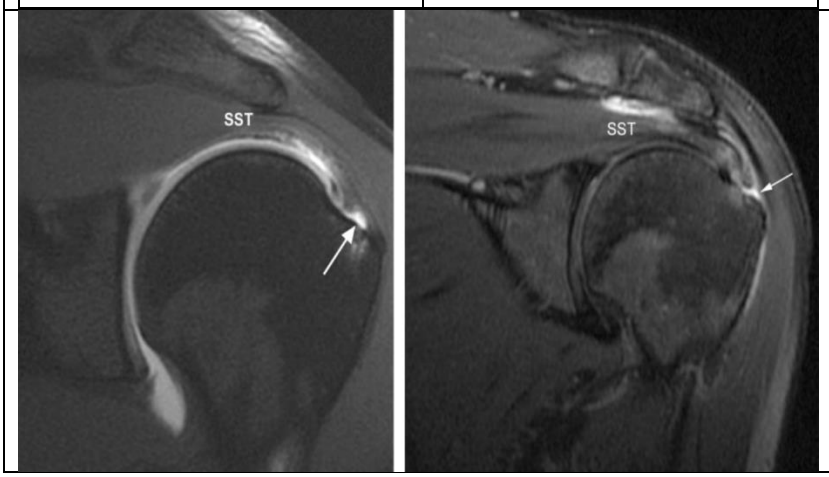


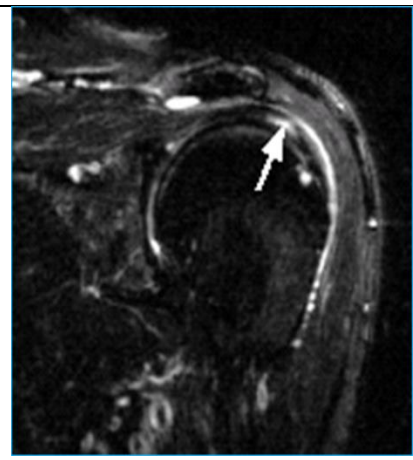
Tendinosis is diagnosed when interstitial signal abnormality is seen without focal disruption of the tendon.



Partial-thickness Supraspinatous Tendon Tear

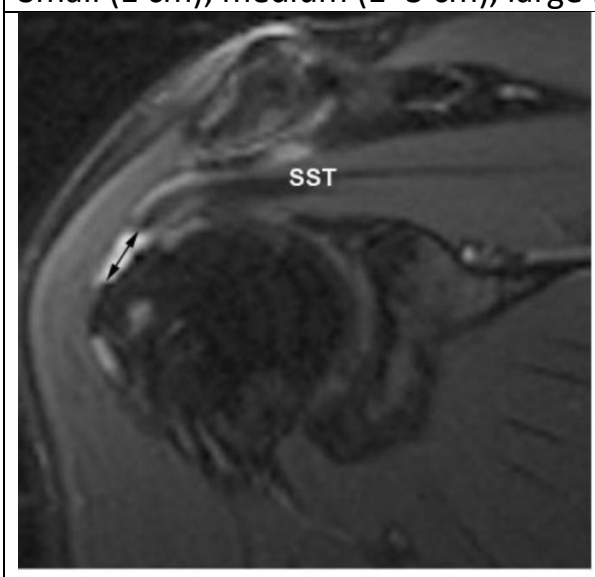
Articular surface	Bursal surface	Interstitial tear



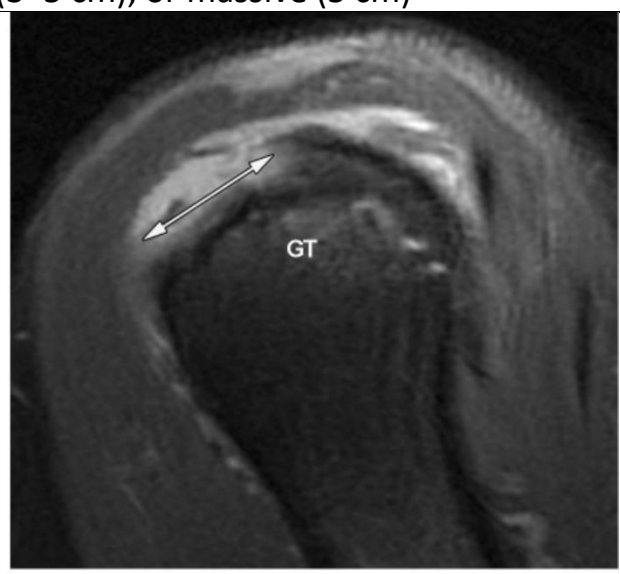


Full-Thickness Supraspinatous Tendon Tear

Small (1 cm), medium (1–3 cm), large (3–5 cm), or massive (5 cm)

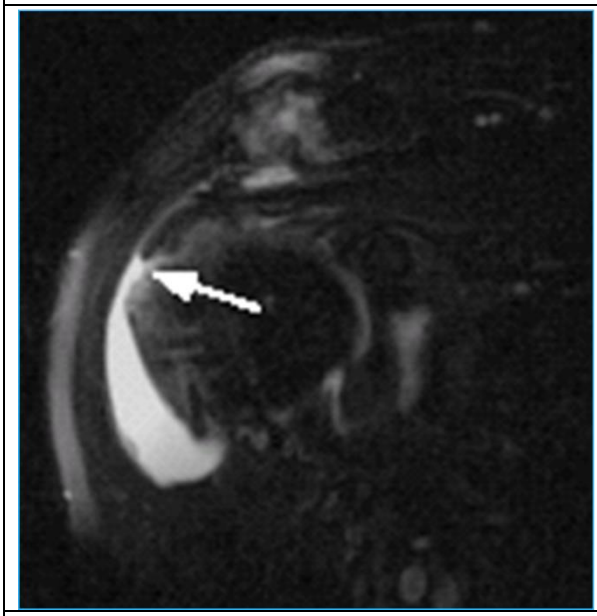


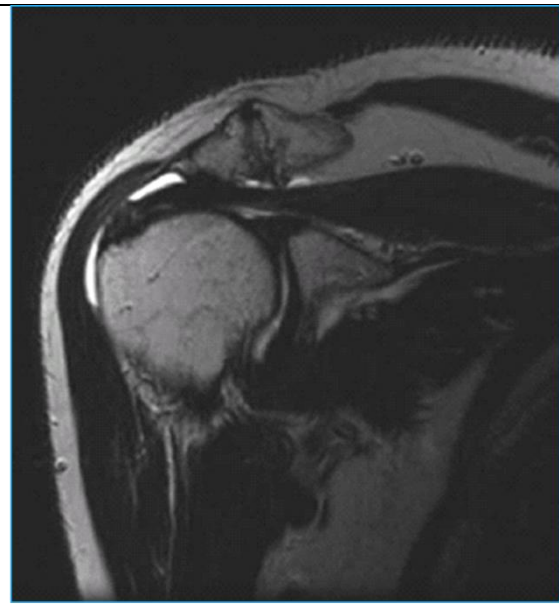
a.



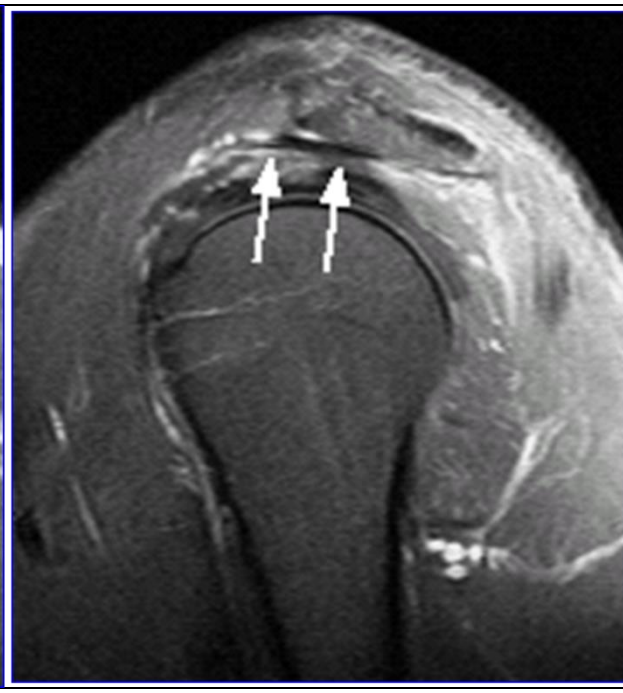
b.

Subacromial-Subdeltoid Bursitis





Thickened Coraco-Acromial Ligament



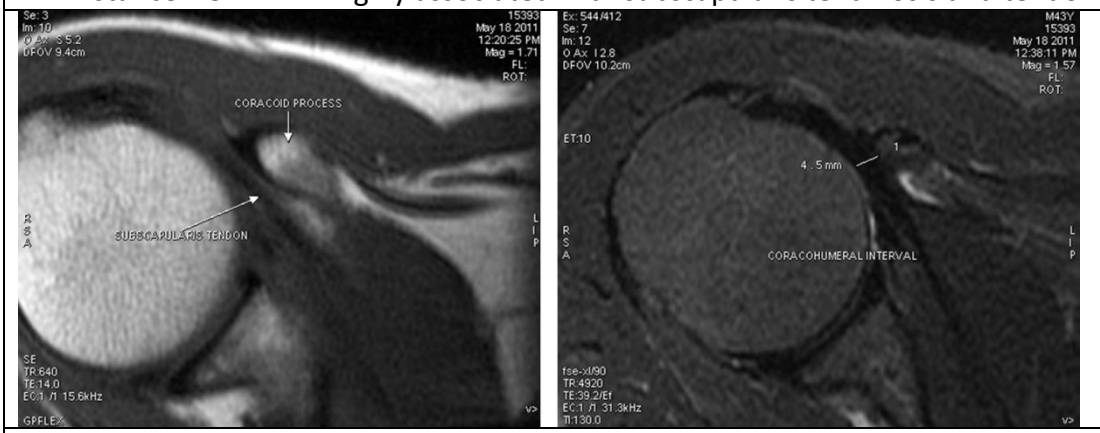
II- Subcoracoid Impingement

- Subcoracoid impingement is an unusual form of shoulder impingement which instead of affecting predominantly the supraspinatus, involves the tendon of subscapularis.
- The space between the tip of the coracoid and the humerus is narrowed, which over time results in tears of the subscapularis tendon.
- Underlying causes include:
    - Previous trauma or surgery to the coracoid
    - Congenital narrowing of the subcoracoid space.

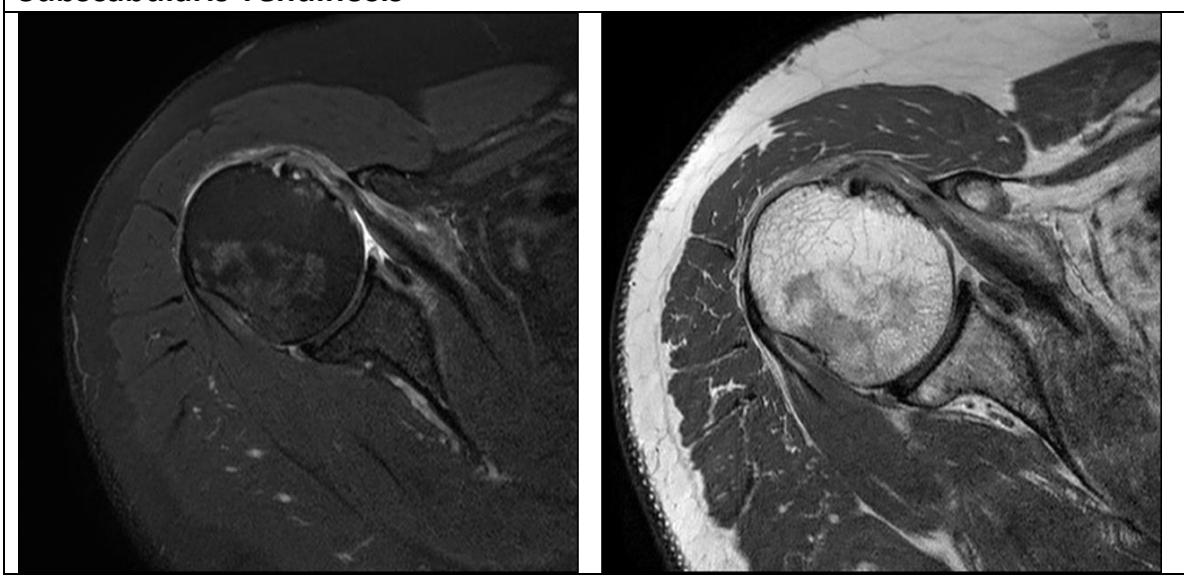
Coraco-humeral Interval:

✓ Normal = distance between the coracoid process and the humeral head is 9-11 mm.

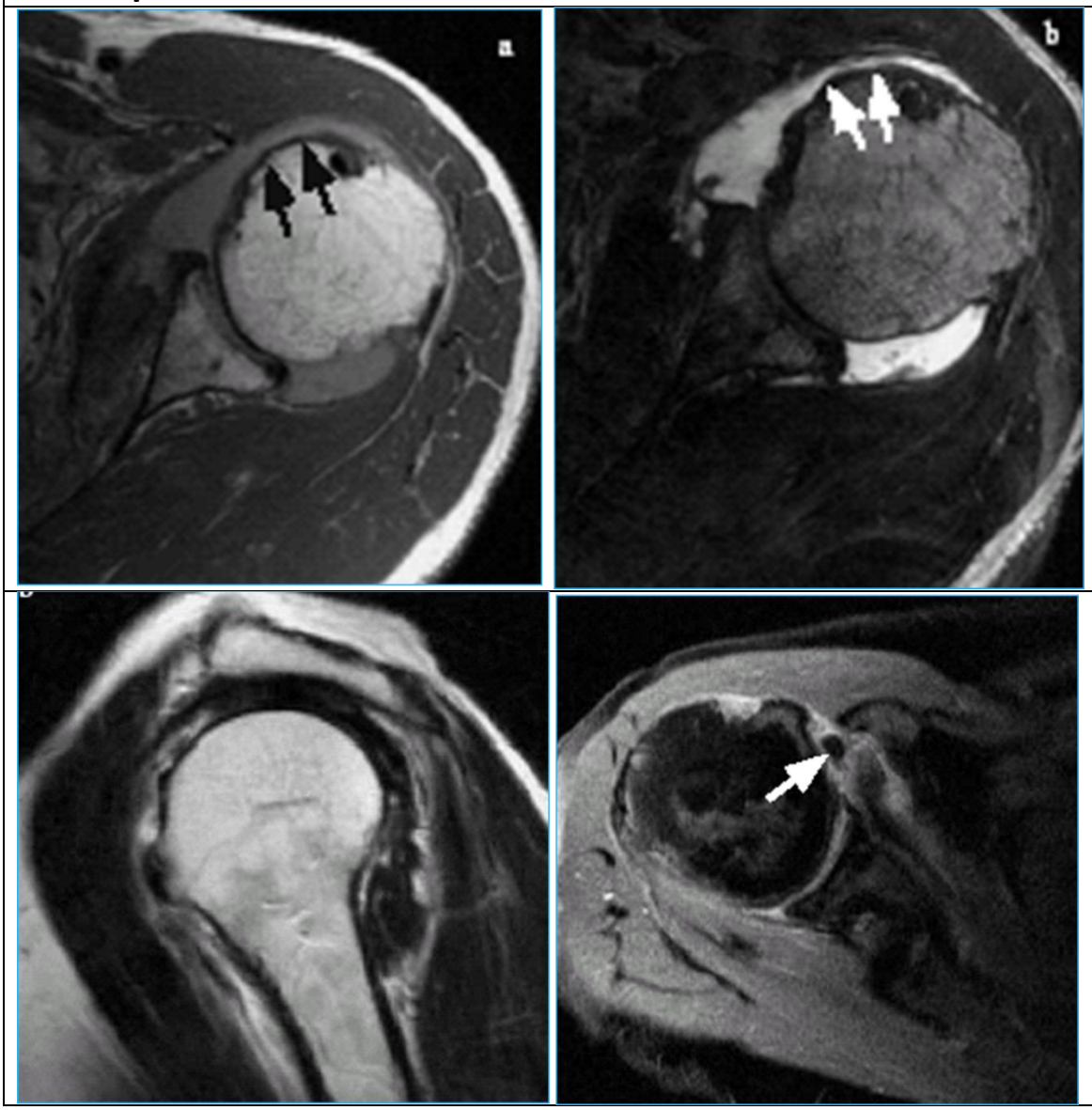
✓ Distance ≤ 5 mm => highly associated with subscapularis tendinosis and tendon tears



Subscabularis Tendinosis



Subscapularis Tear



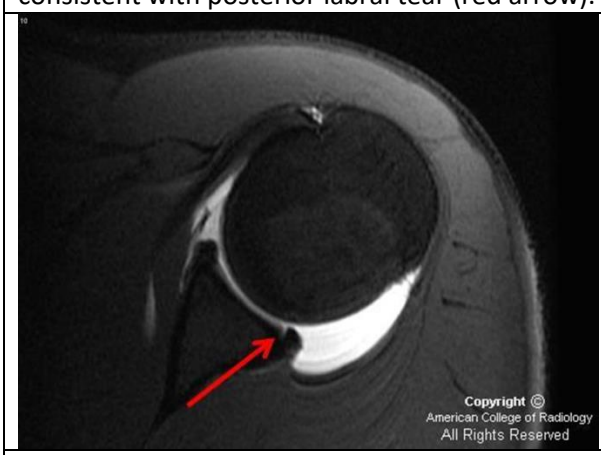
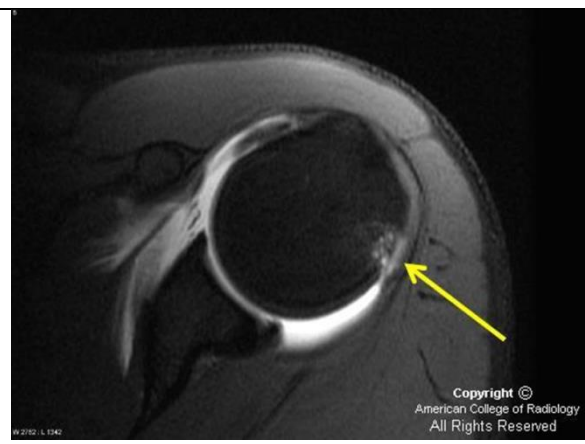
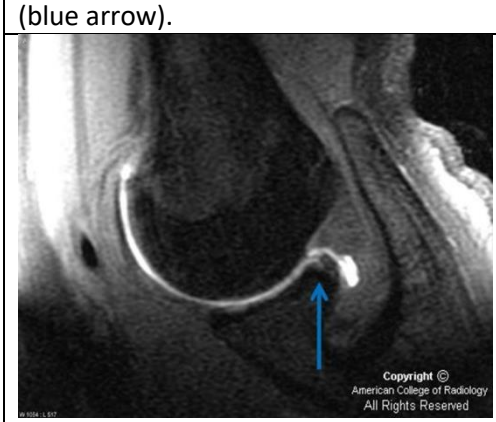
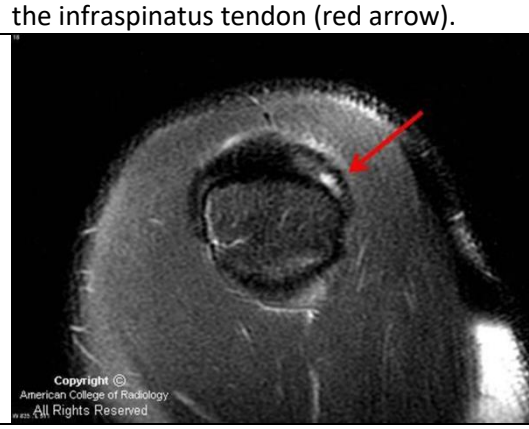
III- Internal Impingement Of Shoulder = Posterosuperior Impingement

- The underlying mechanism of injury in internal impingement involves compression of the supraspinatus or infraspinatus tendons between the humeral head and the posterior glenoid labrum which represents an exaggeration of normal physiologic contact between the rotator cuff and glenoid during extreme abduction/external rotation; condition affecting overhead throwing athletes.

<u>Imagimg findings:</u>

- ✓ Partial thickness articular surface tears of the posterior fibers of the supraspinatus and/or anterior fibers of the infraspinatus
- ✓ Posterosuperior labral tear or fraying.
- ✓ Cystic changes in the superior humeral head and osteochondral lesions underlying the infraspinatus tendon.

Axial T1 fat-sat suppressed MR arthrogram

Abnormal contrast extension beneath posterior superior labrum at labrocartilaginous junction consistent with posterior labral tear (red arrow).	Subcortical cystic changes in the posterolateral humeral head (yellow arrow).
	
T1 fat-suppressed MR arthrogram image with the patient in ABER (Abduction External Rotation positioning) confirms a tear of the posterior labrum (blue arrow).	Sagittal T1 fat-suppressed MR arthrogram image exhibits a low-grade partial thickness articular surface insertional tear of the anterior fibers of the infraspinatus tendon (red arrow).
	

Proximal Humeral Epiphysiolysis
"Little League Shoulder"

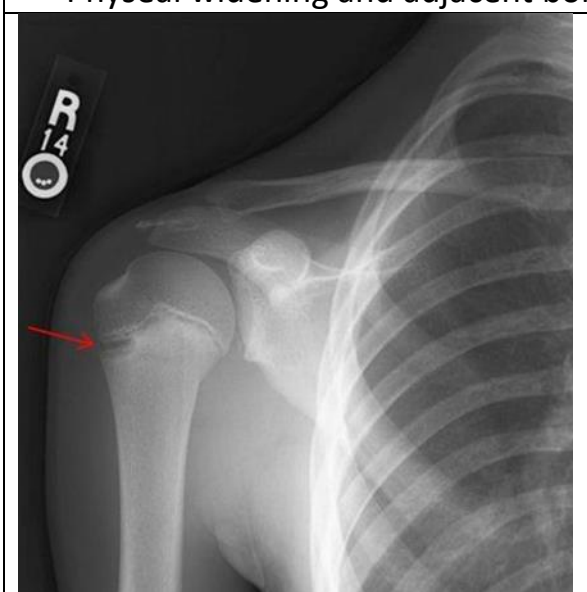
- Proximal humeral epiphysiolysis is a common overuse injury of the shoulder among young baseball pitchers.
- Age = 11–16 years old
- Clinical picture: gradual onset of pain localized to the proximal humerus during the act of throwing, or tenderness to palpation over the proximal humerus.

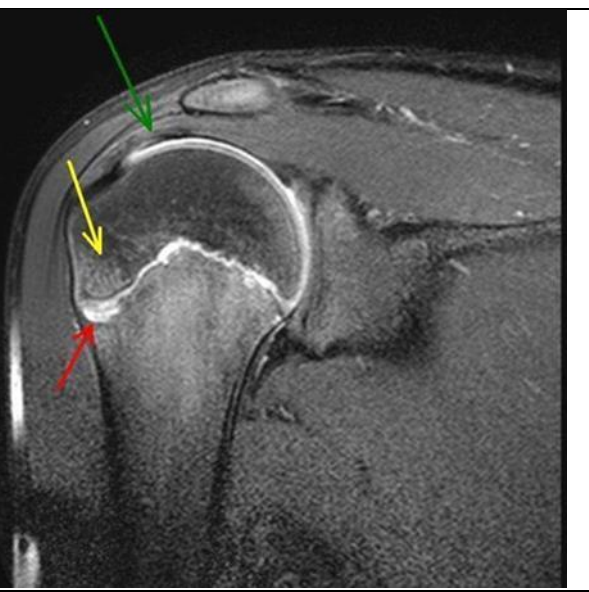
Plain Radiographic Findings:

- Lateral physeal widening
- Demineralization adjacent to the physis
- Lateral metaphyseal fragmentation
- and/or sclerosis of the proximal humeral metaphysis.

MRI Findings:

- Physeal widening and adjacent bone marrow edema.

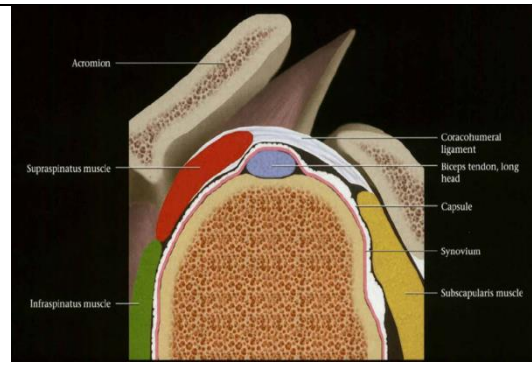




Rotator Interval and Biceps Pulley Lesions

❖ Rotator Interval Anatomy

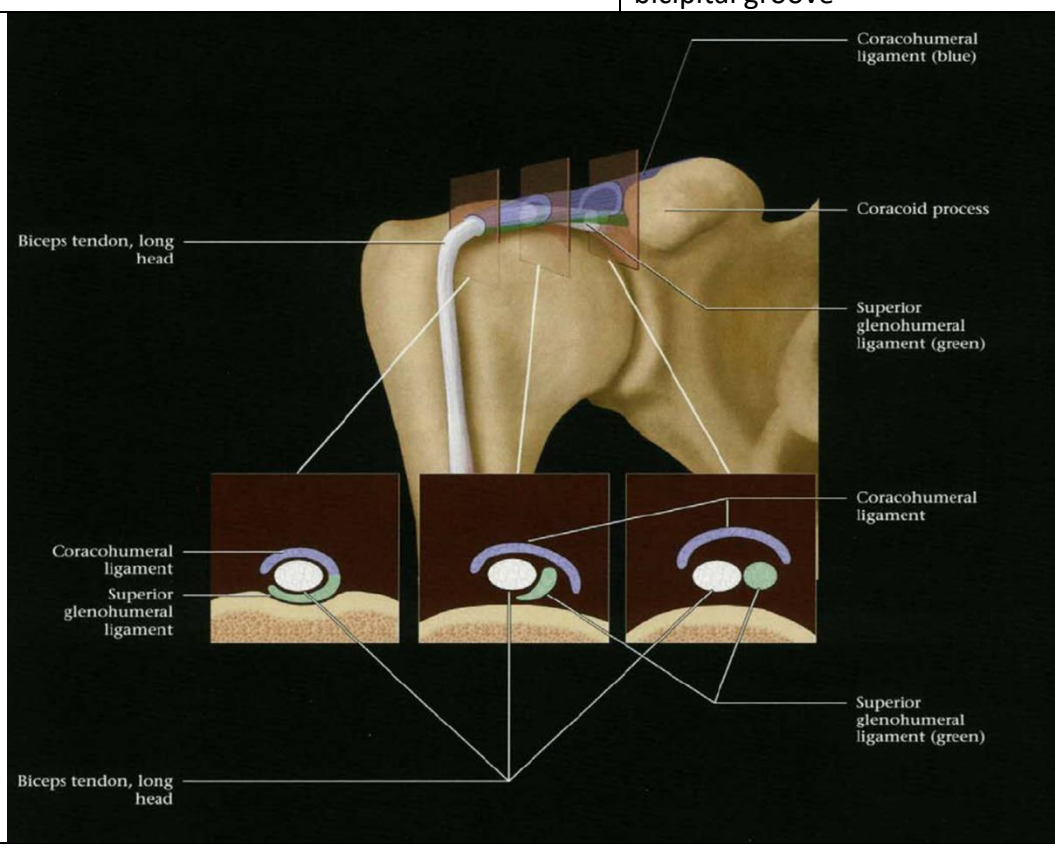
- Triangular space between supraspinatus (SSP) and subscapularis tendons (SSC)
- Base of triangle: at coracoid process
- Tip of triangle: at transverse ligament
- Medial extent: Coracoid base
- Lateral extent: Entrance to bicipital groove, transverse ligament
- Floor: Humeral head cartilage
- Roof: Joint capsule



❖ Contents of rotator interval = Biceps Pulley

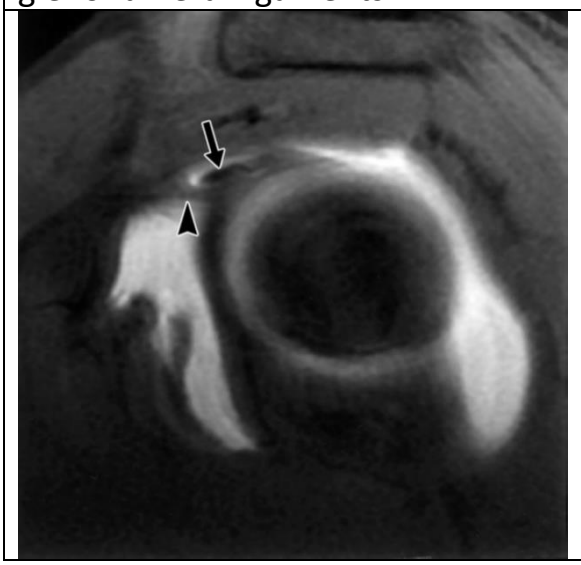
- Coracohumeral ligament (CHL)
- Superior glenohumeral ligament (SGHL)
- Biceps tendon, long head (LHBT)

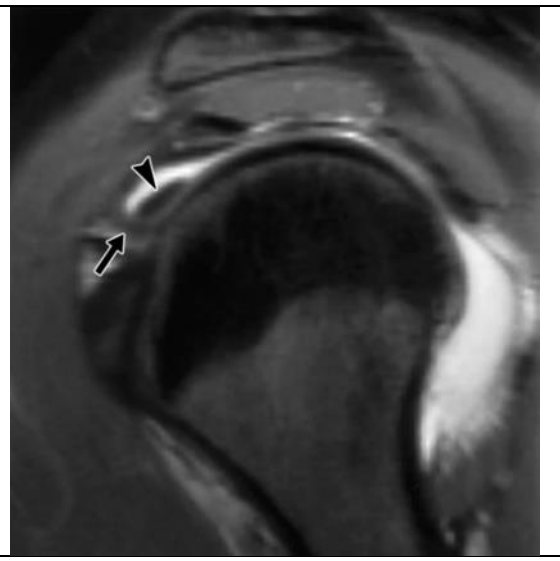
Coracohumeral ligament and superior glenohumeral ligament stabilize long head of biceps tendon as it enters bicipital groove



❖ Sagittal T1 MR Arthrogram

Long head of biceps tendon (arrow) enveloped by contrast agent– distended “sling” (arrowhead) formed by coracohumeral and superior glenohumeral ligaments.



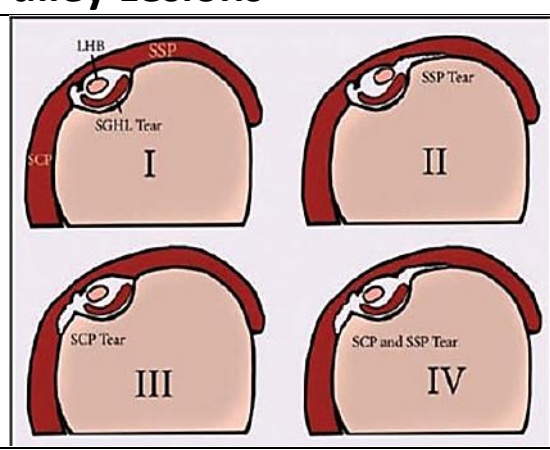


A- Anterosuperior Impingement

Impingement of the deep surface of the subscapularis tendon and the biceps pulley against the anterosuperior glenoid rim in a position of horizontal adduction and internal rotation of the arm.

❖ Habermeyer Classification of Pulley Lesions

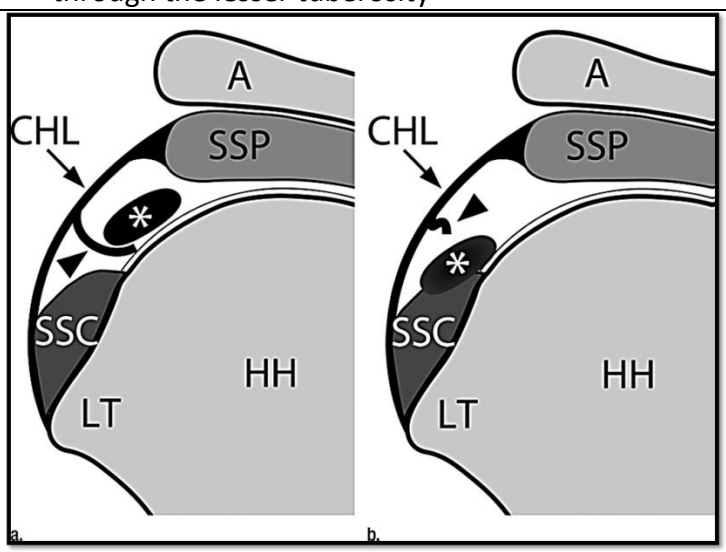
Group	Pathologic Finding
I	Isolated tear of the SGHL
II	Tear of the SGHL and tear of the adjacent SSP tendon
III	Tear of the SGHL and tear of the adjacent SSC tendon
IV	Tear of the SGHL and tears of the adjacent SSC and SSP tendons

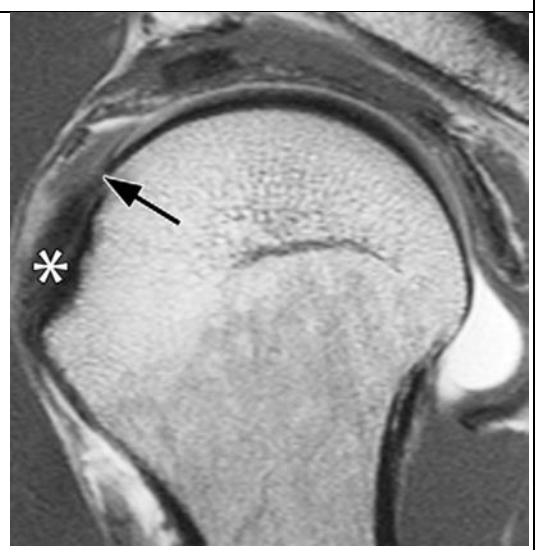


Habermeyer Group 1 Lesion

Displacement Sign

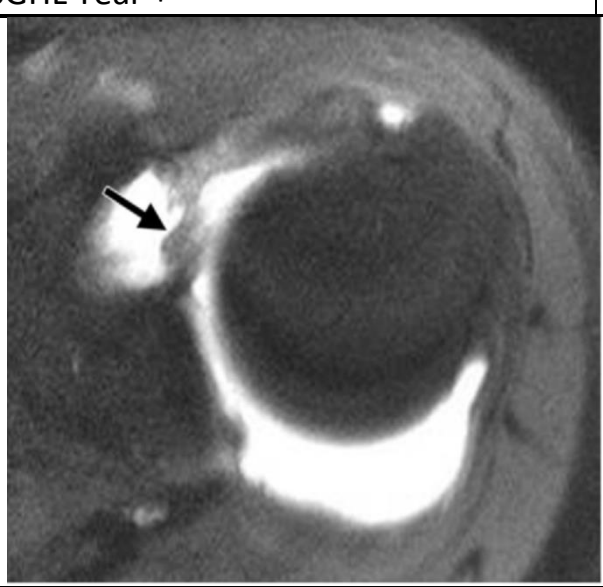
- Oblique sagittal sections illustrate normal anatomy of the rotator interval on a midsection through the lesser tuberosity.
- The SGHL (arrowhead) and CHL (arrow) form a sling that prevents the LHBT (∗) from medial and caudal dislocation.
- If SGHL (arrowhead) is torn, the LHBT (∗) dislocates caudal onto the superior border of the SSC tendon => direct contact of the displaced LHBT and the SSC tendon on a midsection through the lesser tuberosity

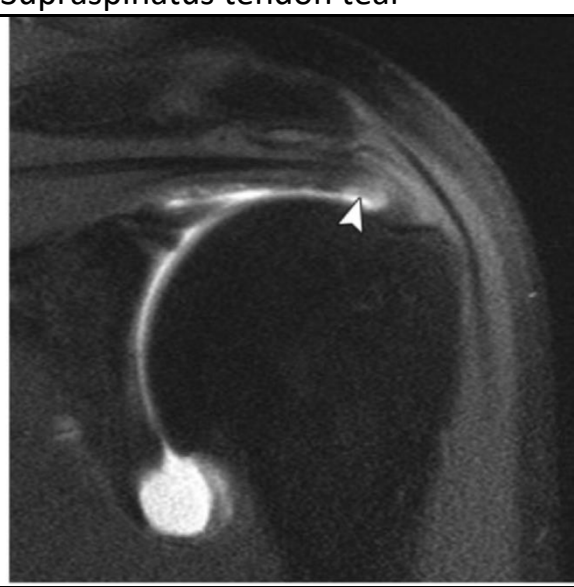




Habermeyer Group 2 Lesion

SGHL Tear +	Supraspinatus tendon tear



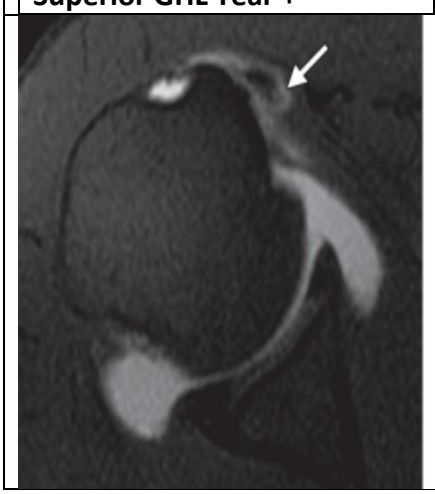


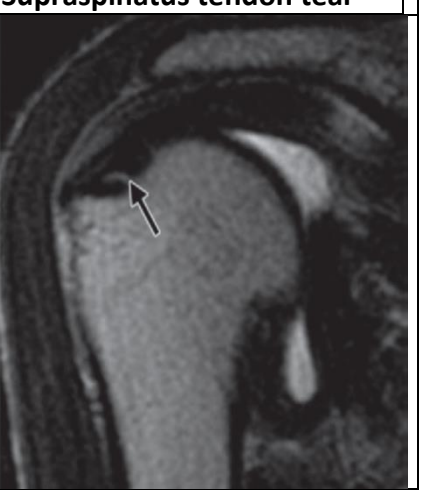
Habermeyer Group 3 Lesion

Partial SSC tear	Displacement sign
Contrast agent entering a defect (arrow) of the superior SSC tendon (arrowhead)	LHBT (arrow) cutting into the superior portion of SSC tendon (arrowhead).

Habermeyer Group 4 Lesion

Superior GHL Tear +	Subscapularis tendon tear	Supraspinatus tendon tear





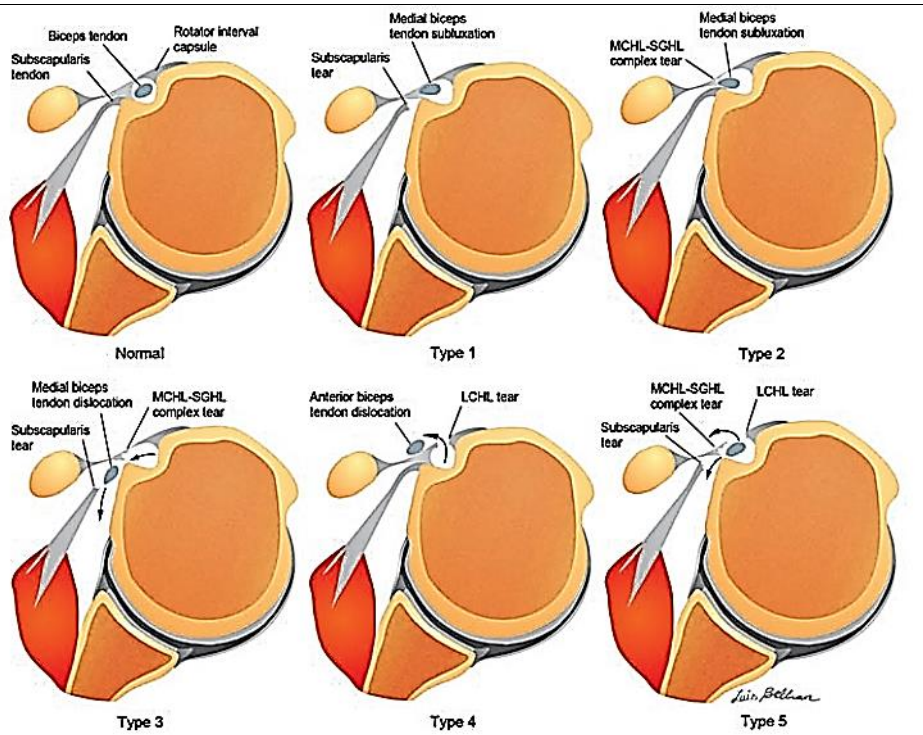
B-Biceps Tendon Instability

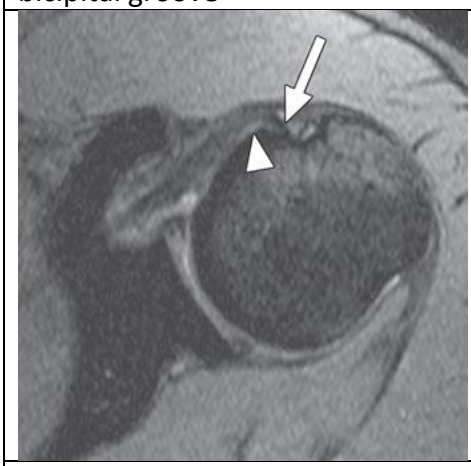
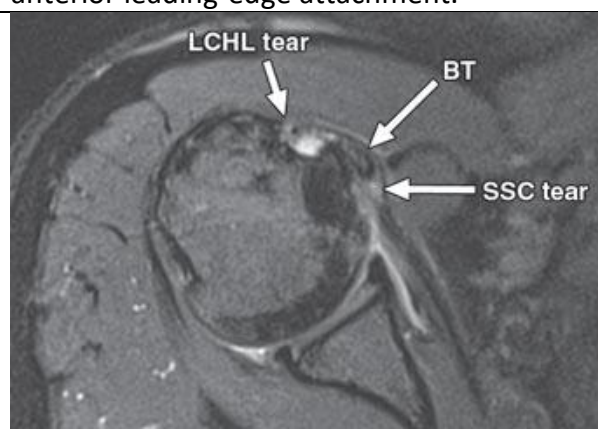
Rotator interval capsule is composed of:

- Coracohumeral ligament (CHL), superior glenohumeral ligament (SGHL), and capsular fibers, which all blend together along insertions medial and lateral to bicipital groove, maintaining biceps tendon within groove.
- Medial aspect of coracohumeral ligament (MCHL) blends with SGHL forming medial sheath (or MCHL–SGHL complex), which along with superior fibers of subscapularis tendon form medial supporting structures of bicipital groove.
- Lateral aspect of coracohumeral ligament (LCHL) blends with most anterior fibers of supraspinatus tendon forming lateral supporting structures of bicipital groove.

❖ Bennett classification of biceps instability

- Type 1 lesions are isolated tears of superior fibers of subscapularis tendon, resulting in medial subluxation of biceps tendon within groove.
- Type 2 represents tear of medial sheath (MCHL–SGHL complex), allowing medial subluxation of biceps tendon.
- Type 3 represents lesion of both medial sheath and subscapularis tendon, allowing medial dislocation of biceps tendon from bicipital groove.
- Type 4 involves LCHL and most-anterior fibers of supraspinatus tendon, allowing biceps tendon to dislocate anterior to subscapularis and coracohumeral ligament.
- Type 5 combines all structures (subscapularis tendon, medial sheath, LCHL, and supraspinatus tendon), which allows biceps tendon to dislocate either anteriorly or medially.



Bennett Type 1 lesion with tiny articular surface tear of cranial fibers of subscapularis tendon along lesser tuberosity attachment (arrowhead) associated with mild medial subluxation of biceps tendon (arrow) within bicipital groove	Bennett type 3. shows medial dislocation of biceps tendon (arrow) from bicipital groove
	
Bennett type 4. Dislocation of biceps tendon anterior (superficial) to subscapularis tendon and coracohumeral ligament.	Bennett type 5 lesion with tearing of subscapularis tendon (SSC) along lesser tuberosity attachment associated with medial dislocation of biceps tendon (BT) from bicipital groove. There is also tearing of lateral coracohumeral ligament (LCHL) and supraspinatus tendon (SSN) along anterior leading-edge attachment.
	

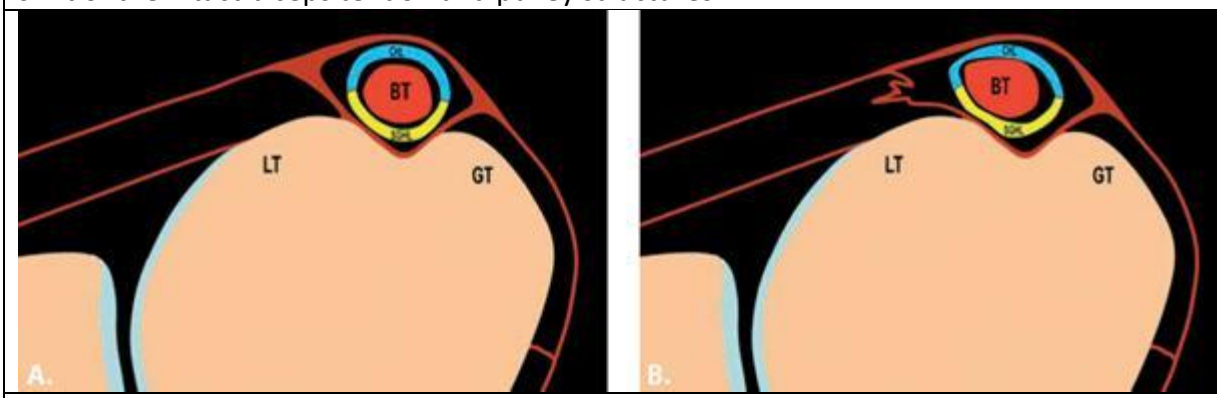
❖ Modified Habermeyer Classification System

(i) Tendon subluxation

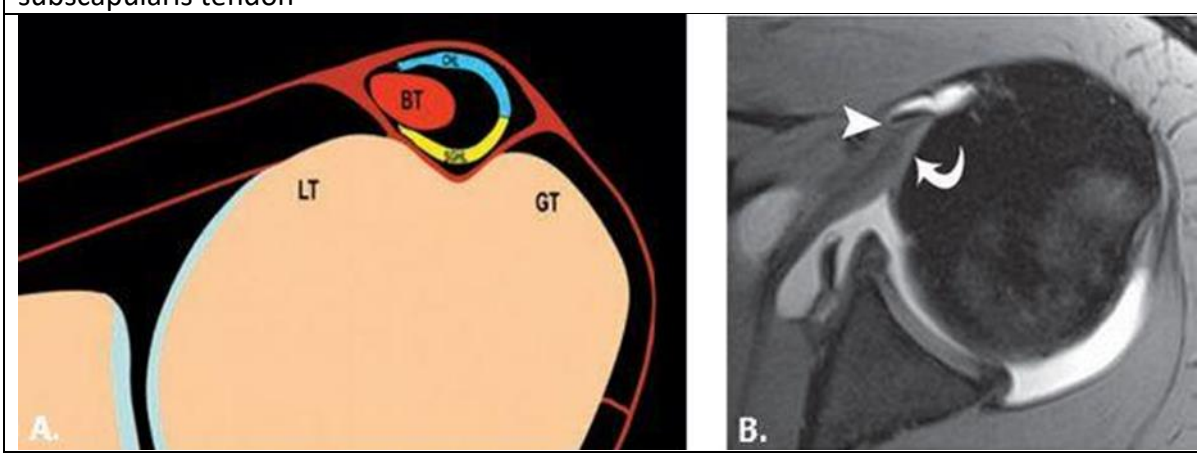
(ii) Extra-articular dislocation

(iii) Intra-articular dislocation

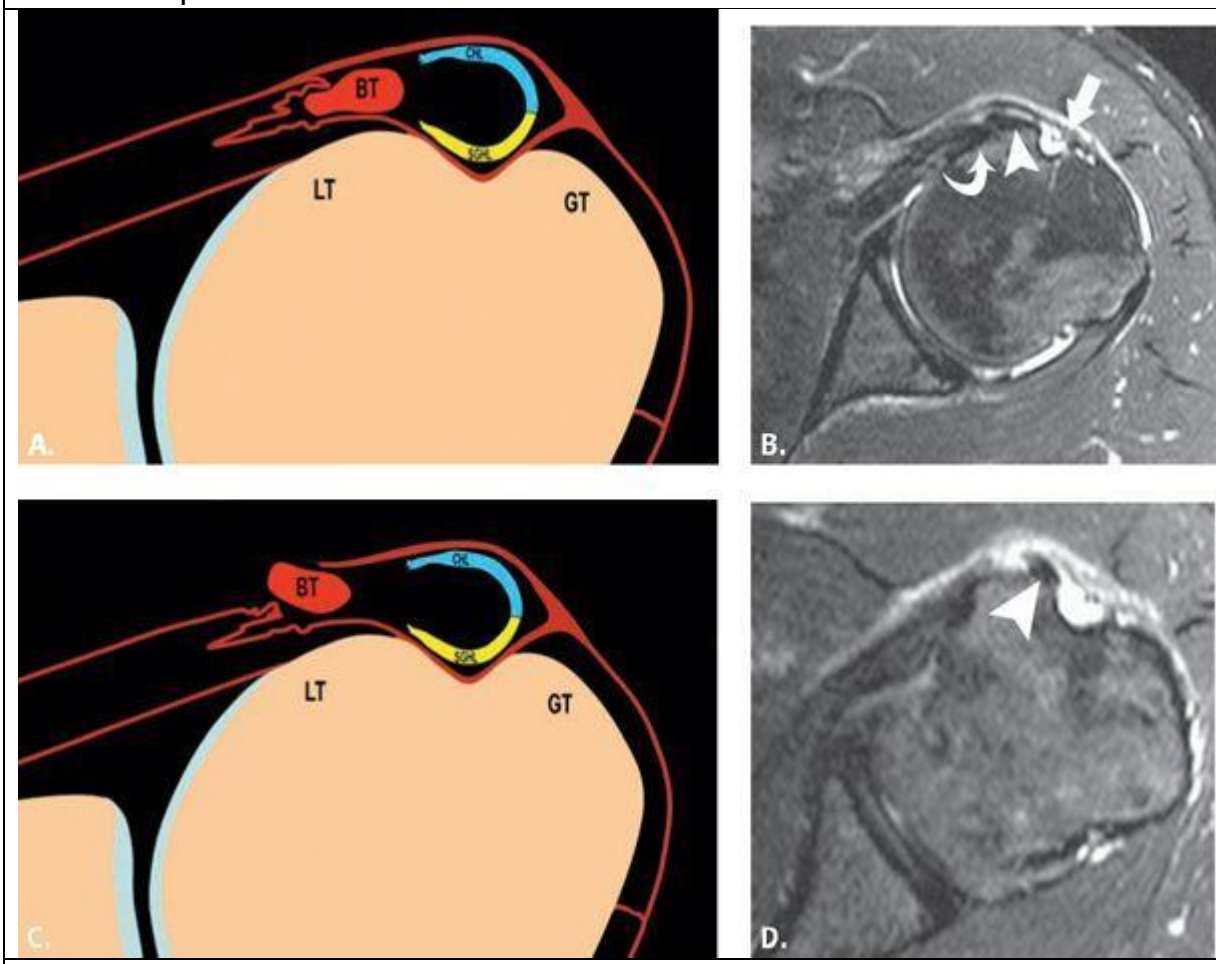
Type 1: Tendon displacement with an isolated subscapularis tendon tear.
A partial intrasubstance or articular-sided tear of the tendon can allow a very minimal medial shift of the intact biceps tendon and pulley structures



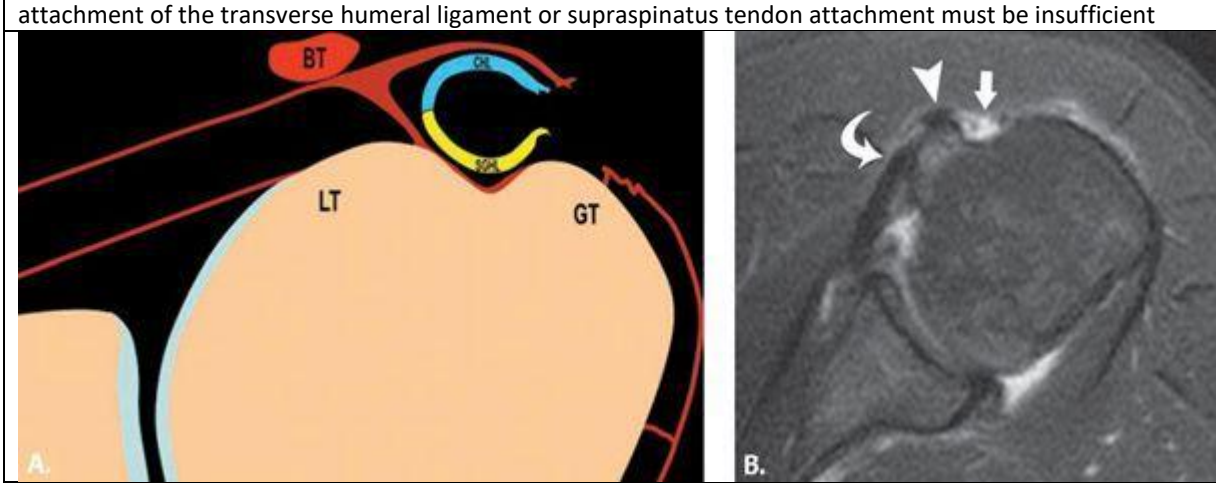
Type 2: Tendon subluxation with a tear of the medial limbs of the biceps pulley (coracohumeral and superior glenohumeral ligaments) and an intact subscapularis. The biceps tendon subluxes medially through the torn pulley but is restrained from further medial subluxation by an intact subscapularis tendon



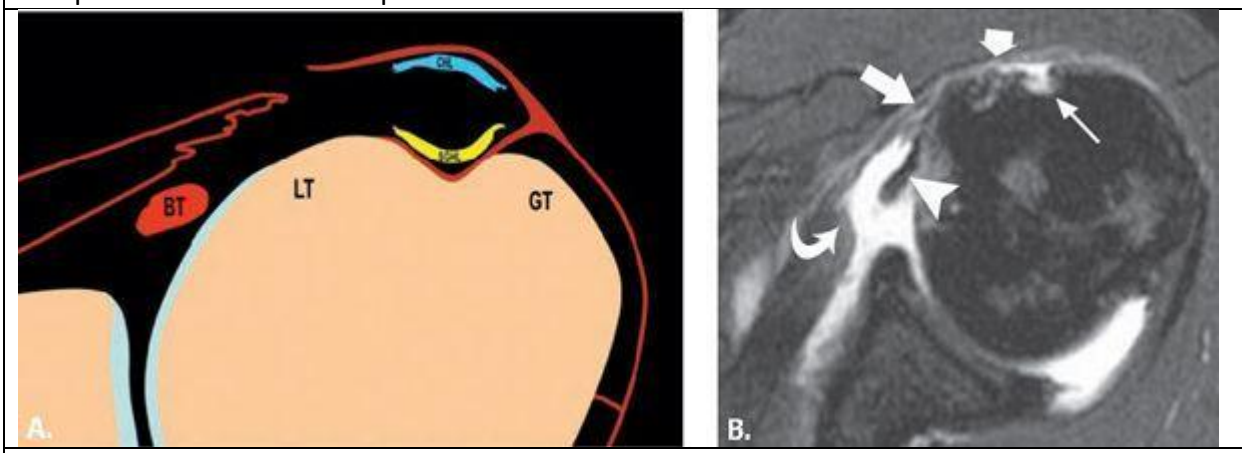
Type 3: Extra-articular tendon dislocation with tears of the medial limbs of the pulley and an intrasubstance tear of the subscapularis tendon. This combination of structural insufficiency results in medial displacement of the biceps tendon into the subscapularis tendon tear



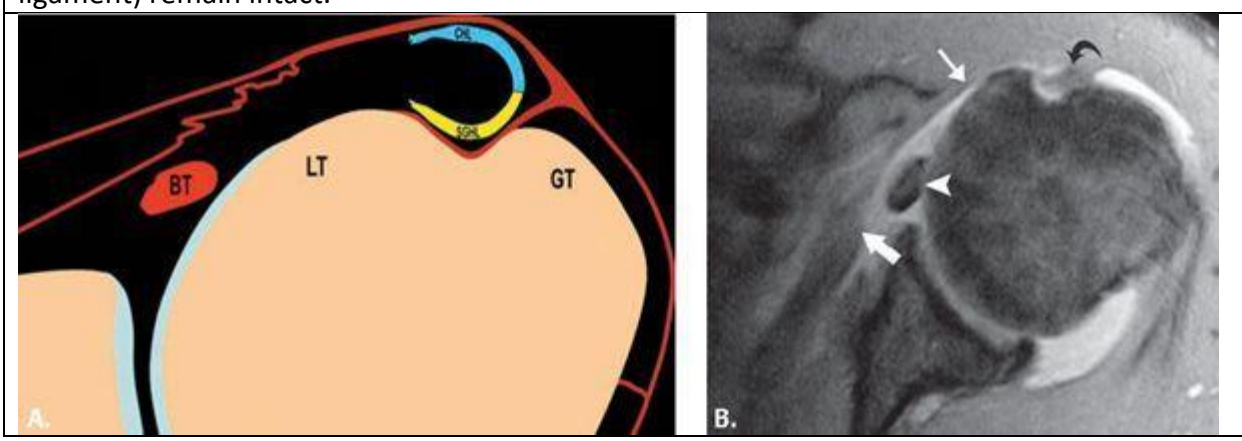
Type 4: An extra-articular tendon dislocation with tears of the lateral limbs of the pulley and an intact subscapularis tendon. For the biceps tendon to dislocate to a superficial location, the greater tuberosity attachment of the transverse humeral ligament or supraspinatus tendon attachment must be insufficient



Type 5: An intra-articular tendon dislocation with tears of the medial limb of the pulley and a complete tear of the subscapularis tendon.



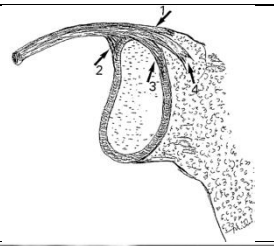
Type 6: An intra-articular tendon dislocation with tears of the medial limbs of the pulley and detachment of the subscapularis from the lesser tuberosity. The continuing fibers of the subscapularis that extend to the greater tuberosity (also called the transverse humeral ligament) remain intact.

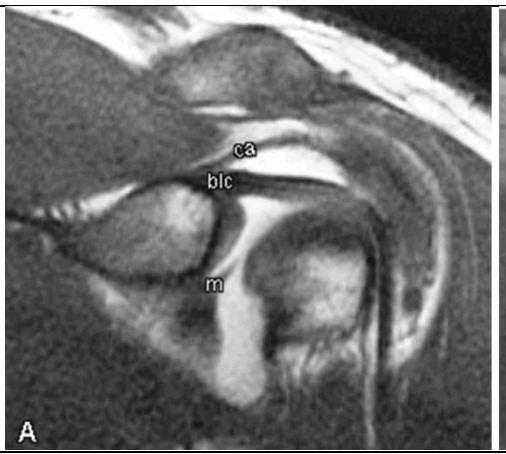


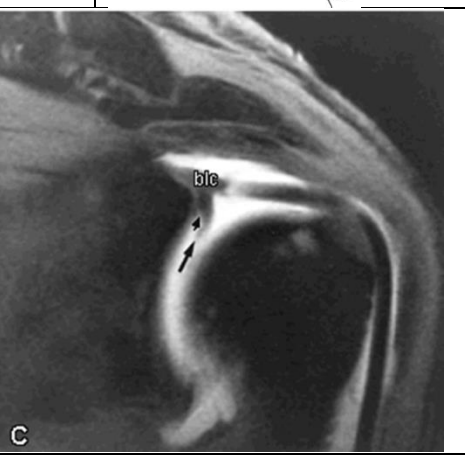
C- SLAP

❖ Normal Biceps Tendon Attachment

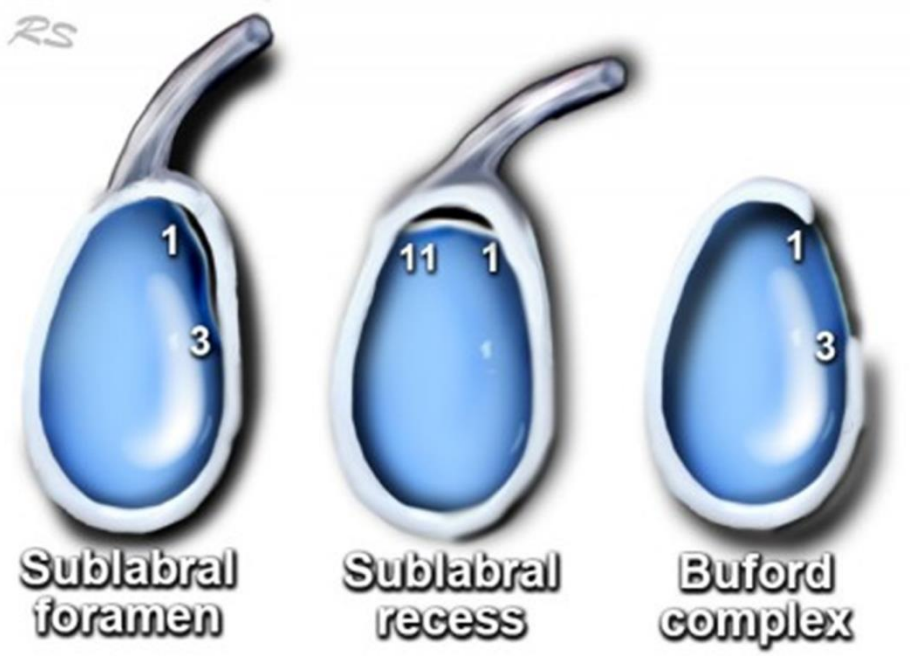
4 Attachments to:
1) Superior glenoid rim
2) Posterosuperior labrum
3) Anterosuperior labrum
4) Base of the coracoid process.





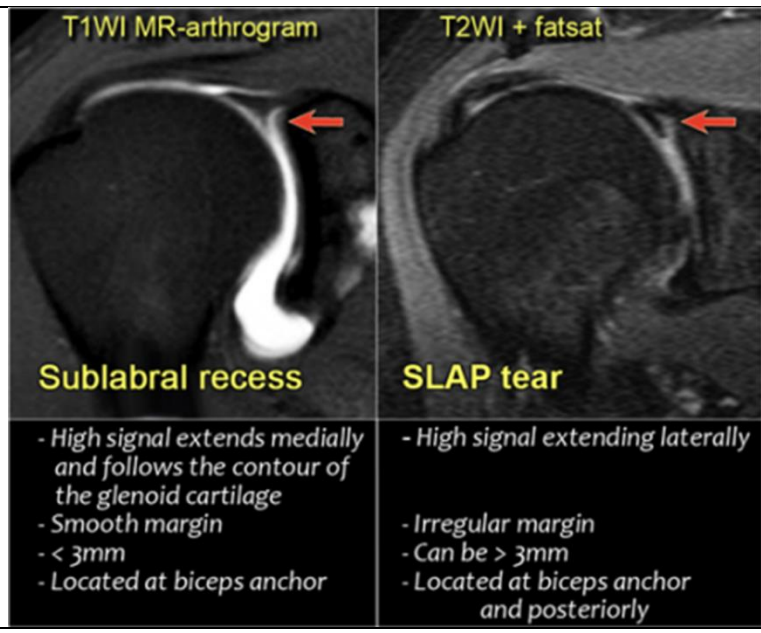


❖ Labral Variants



1) Sublabral Recess (Sulcus)

- Located along superior labrum
- At 12 o'clock position
- represents a normal recess between biceps/superior labrum and the cartilage of the glenoid cavity.
- 1-2 mm in thickness along the full anterior to posterior extent
- Does not extend posterior to biceps tendon
- Fluid may extend into recess simulating tear
- Medial or vertical orientation of fluid between base of labrum & cartilaginous margin of glenoid rim suggests recess
- Laterally angulated, irregular fluid cleft distal to
- glenolabral attachment suggests tear
- o May be continuous with sublabral foramen

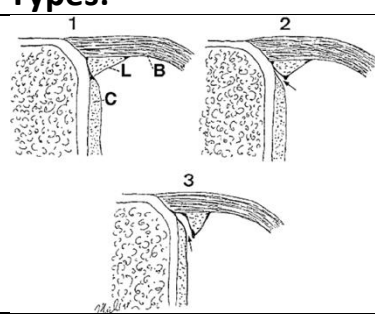


Biceps Labral Complex (BLC) Attachment Types:

Type 1 BLC: No sulcus

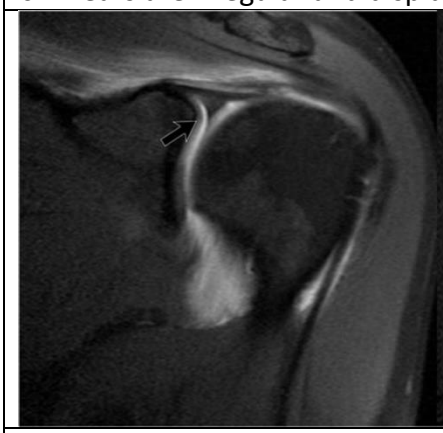
Type 2 BLC: Small sulcus

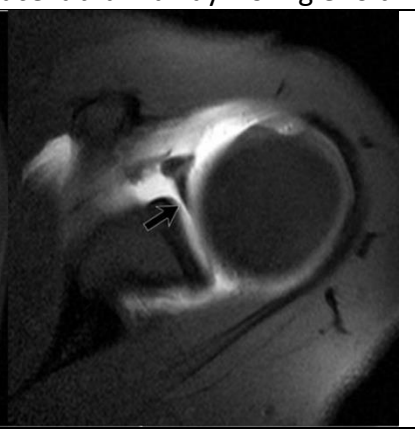
Type 3 BLC: Large sulcus

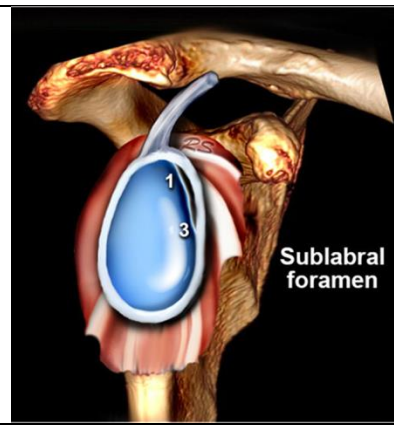


2) Sublabral Foramen (Hole)

- 12 -3 o'clock position
- represents localized detachment of the labrum from the glenoid rim.
- Anterosuperior quadrant of labrum only
- Can mimic tear if filled with fluid or contrast
- Foramen is smooth and tapered
- Tears are irregular and displace labrum away from glenoid when filled with fluid





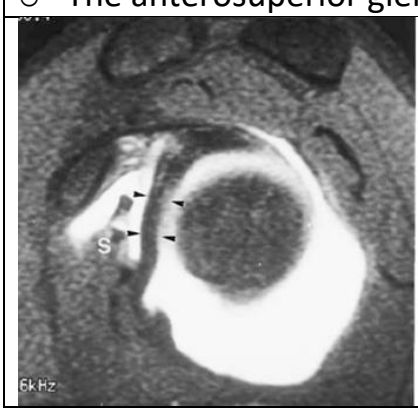


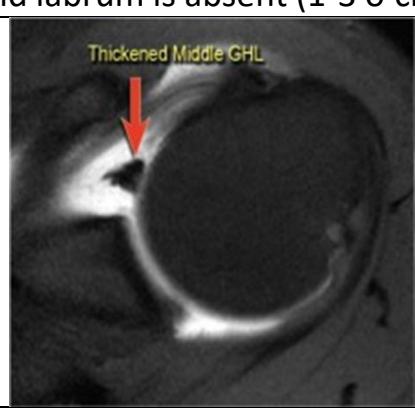
Sublabral Foramen With Sulcus
Between Biceps Tendon & Superior Labrum

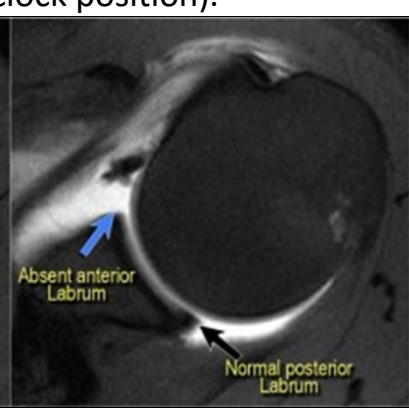
- Double oreo cookie" sign on coronal oblique MR
- Glenoid cortex (black) + sublabral recess (white) + labrum (black) + biceps/superior labrum sulcus (white) + biceps tendon (black)
- Similar appearance can be seen with superior labral tear instead of biceps/superior labrum sulcus

3) BUFORD COMPLEX

- The middle glenohumeral ligament is thick and cord-like.
- The anterosuperior glenoid labrum is absent (1-3 o'clock position).

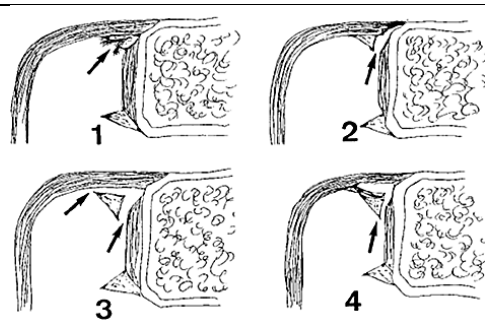






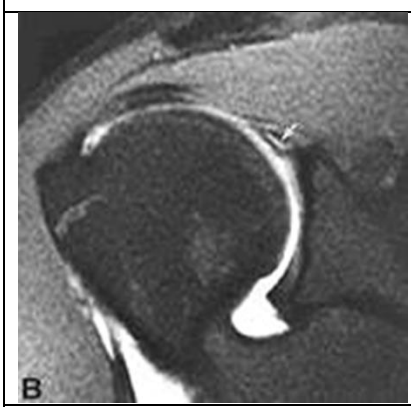
❖ SLAP Classification

Type I: tear confined to the superior labrum
Type II: labrum and biceps tendon detached from the superior glenoid rim.
Type III: bucket handle tear of the superior labrum
Type IV: bucket handle tear of the superior labrum with lateral extension into the biceps tendon



Type I SLAP lesion

Coronal MR Arthrogram
Fraying with ill- defined margins
Normal labral shape with intrasubstance signal



Type II SLAP lesion

Detachment of the Superior labrum from the bony glenoid +
Lateral extension of the tear of superior labrum
Contrast material between the superior labrum and the glenoid (arrow).

Type III SLAP lesion

Contrast material between the labrum and the glenoid (straight arrow)
Contrast material between the labrum and the biceps tendon (t) (curved arrow).

Type IV SLAP lesion.

Separation of the superior labrum from the glenoid (arrow).
Extension of the tear into the biceps tendon (arrowhead

D- Adhesive Capsulitis = Frozen Shoulder

- Idiopathic adhesive capsulitis is a self-limiting disease that is characterized clinically by the gradual onset of severe shoulder pain with restricted shoulder motion of unknown cause.

Adhesive capsulitis may be associated with:

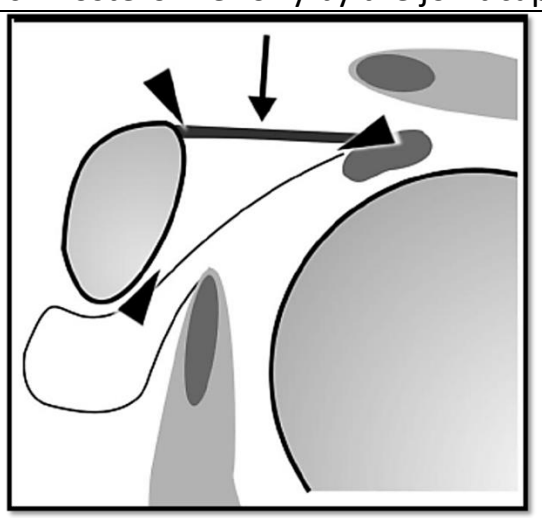
i. **Diabetes mellitus**
ii. Conditions such as dupuytren disease
iii. Hyper- or hypothyroidism
iv. Cerebral, cardiac, and respiratory conditions
v. Surgical procedures that do not directly affect the shoulder, such as cardiac surgery

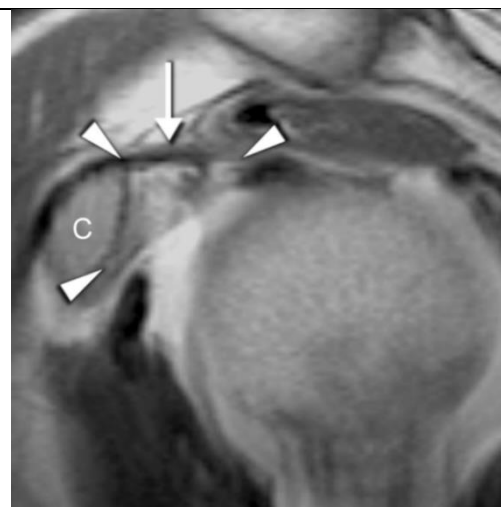
❖ Normal Subcoracoid Fat Triangle

Oblique Sagittal T1 MR Arthrogram

Borders of the triangle (arrowheads):

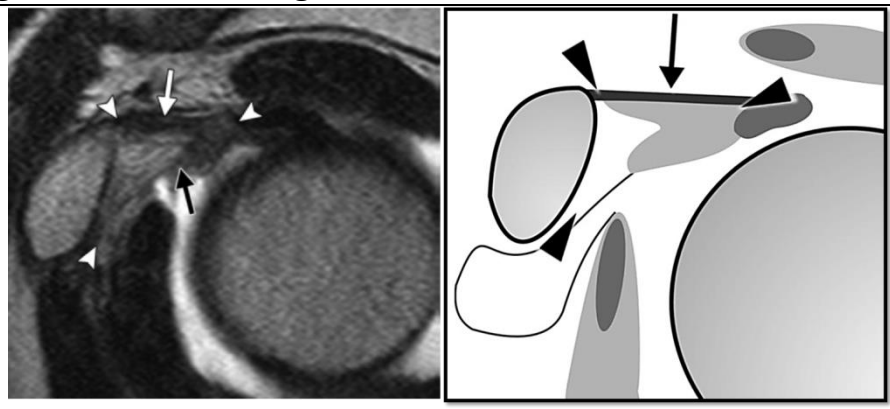
- Anterosuperiorly by the coracoid process (C)
- Superiorly by the Coracohumeral ligament (arrow)
- Posteroinferiorly by the joint capsule.





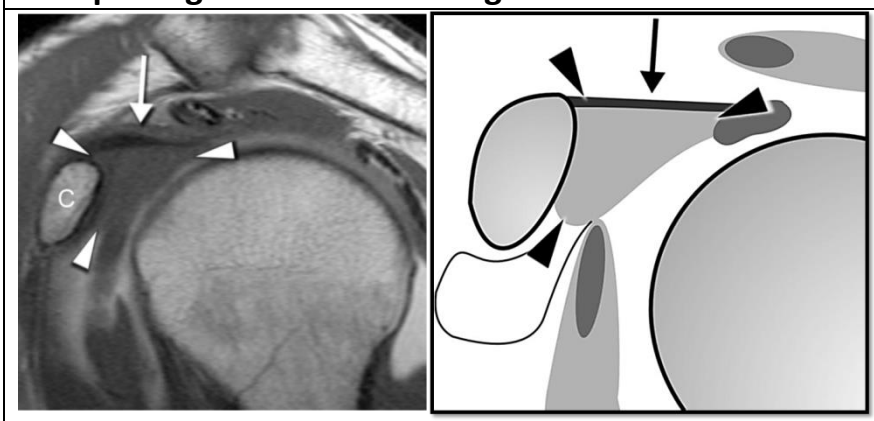
❖ Partial Obliteration of Subacromial Fat triangle

Oblique Sagittal T1 MR Arthrogram



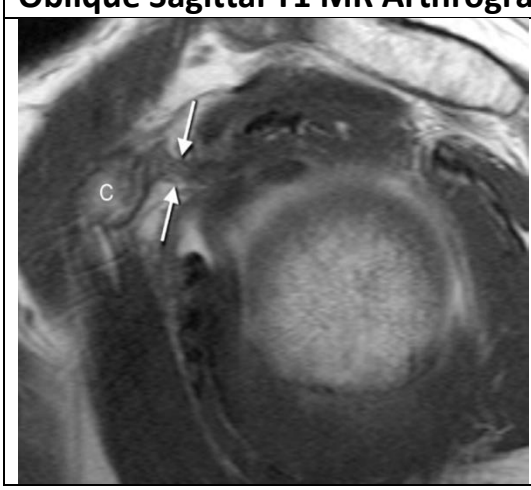
❖ Complete Obliteration of Subcoracoid Fat Triangle

Oblique Sagittal T1 MR Arthrogram



❖ Thickened CHL (Arrows)

Oblique Sagittal T1 MR Arthrogram



Shoulder Fractures

❖ 4 Segment Neer Classification of Proximal Humerus Fracture

- The 4 segments involved are:
  - Greater tuberosity
  - Lesser tuberosity
  - Humeral head articular surface
  - Humeral diaphysis.

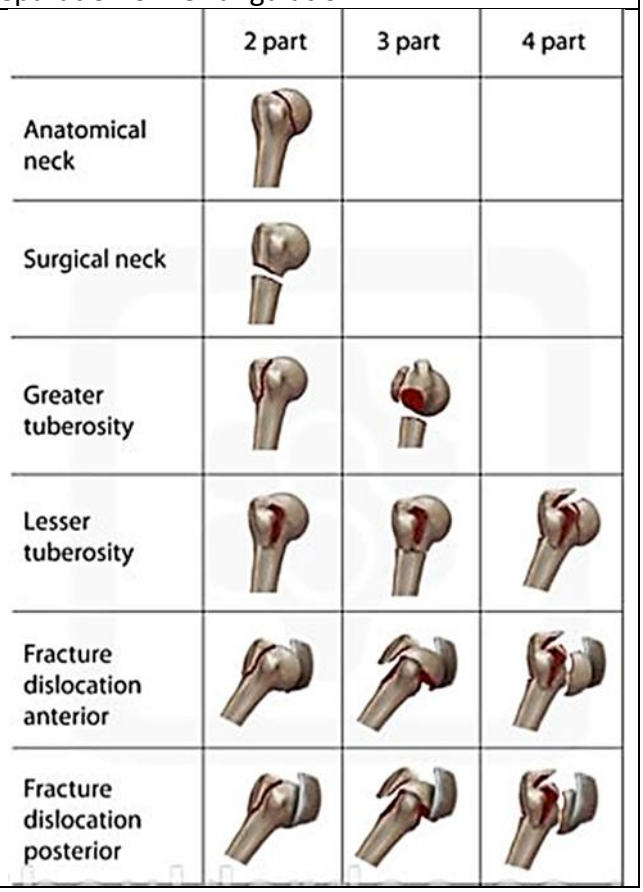
- A segment is defined as displaced if > 1 cm separation or 45° angulation.

One-Part Fractures
No fragments meet the criteria for displacement.

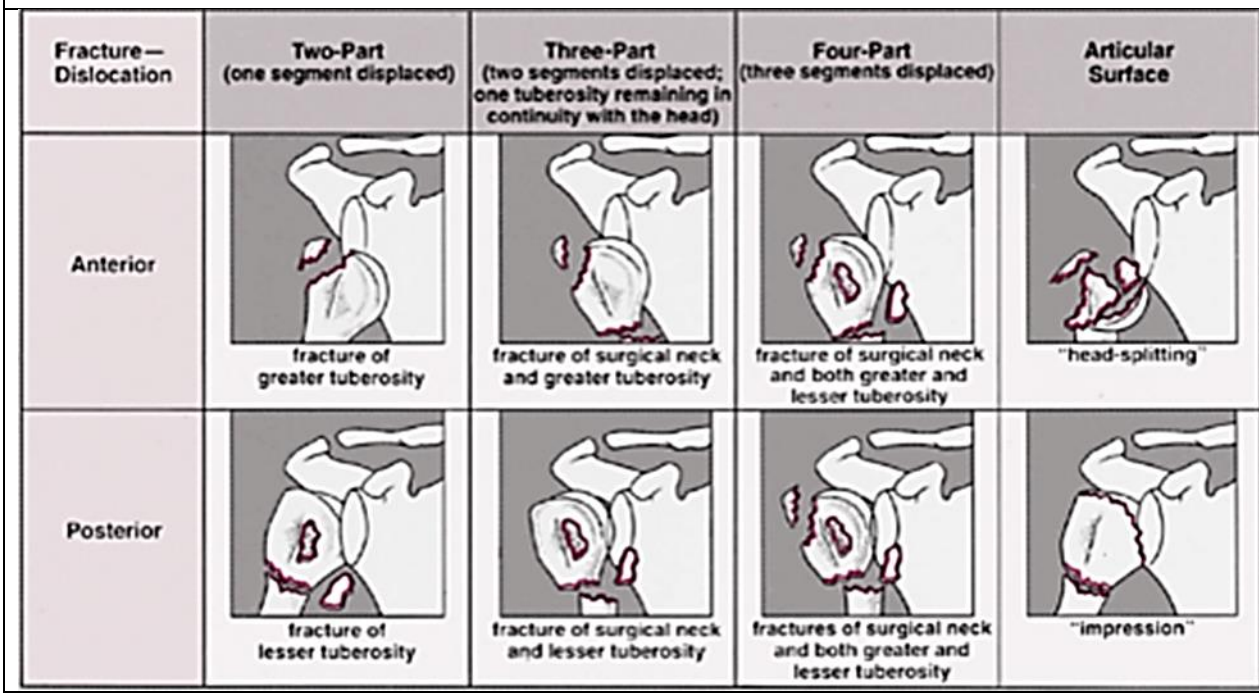
Two-Part Fractures
One segment is displaced, which may be the greater tuberosity, lesser tuberosity, or articular segment at the level of the anatomic neck or surgical neck.

Three-Part Fractures
One tuberosity is displaced and the surgical neck fracture is displaced. The remaining tuberosity is attached, which produces a rotational deformity.

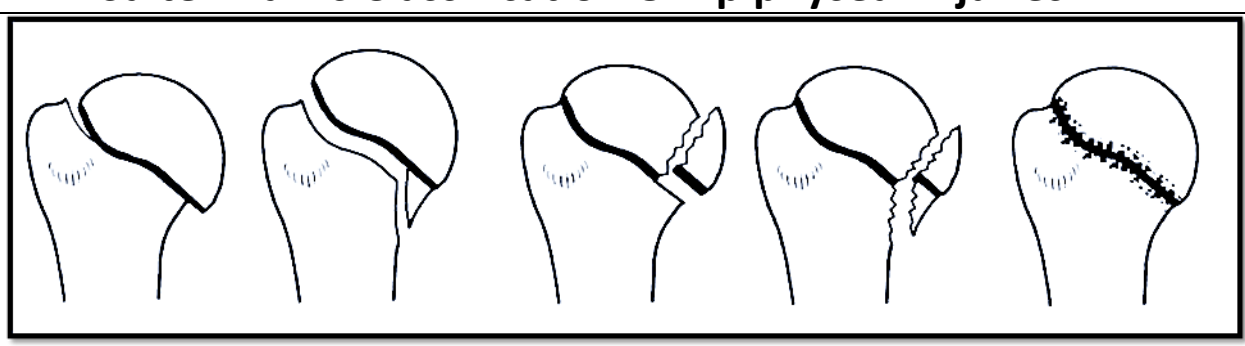
Four-Part Fractures
All four segments (both tuberosities, the articular surface, and the shaft) meet criteria for displacement. The articular segment typically is laterally displaced and out of contact with the glenoid. This is a severe injury and carries a high risk of avascular necrosis.



❖Fracture- Dislocation

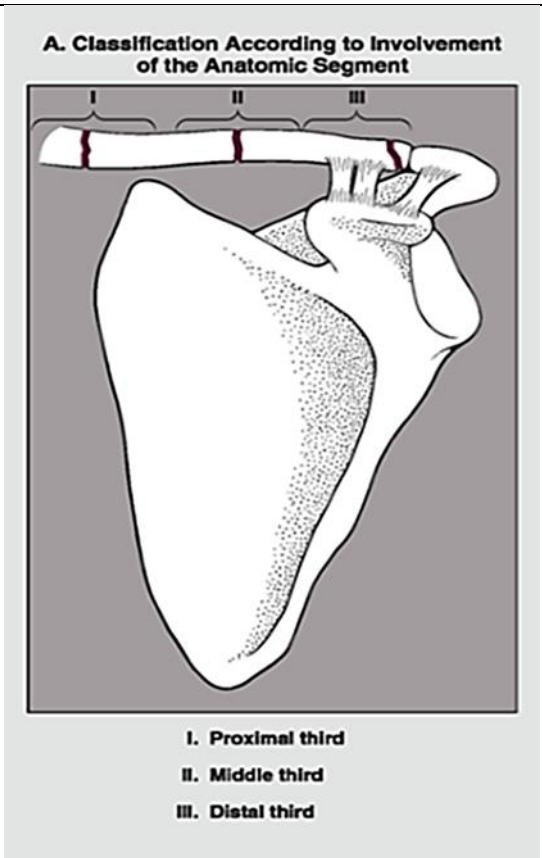

Fracture—Dislocation
Two-Part (one segment displaced)
Three-Part (two segments displaced; one tuberosity remaining in continuity with the head)
Four-Part (three segments displaced)
Articular Surface
Anterior
fracture of greater tuberosity
fracture of surgical neck and greater tuberosity
fracture of surgical neck and both greater and lesser tuberosity
"head-splitting"
Posterior
fracture of lesser tuberosity
fracture of surgical neck and lesser tuberosity
fractures of surgical neck and both greater and lesser tuberosity
"impression"

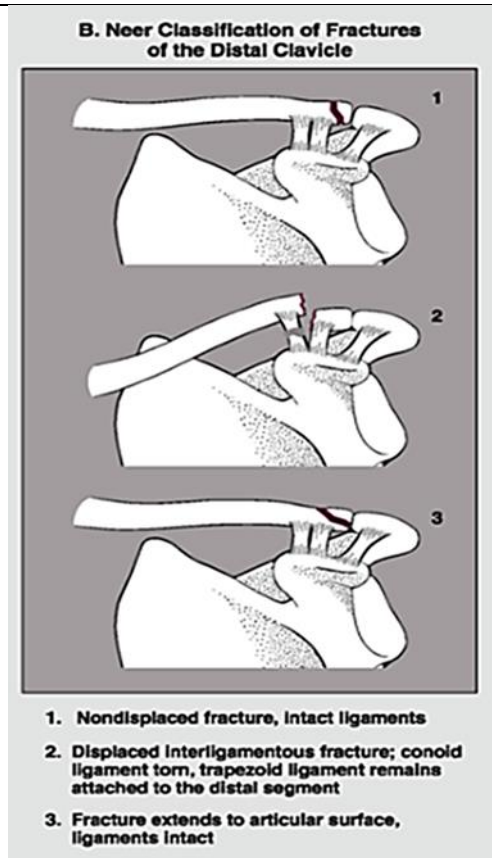
❖ Salter-Harris Classification Of Epiphyseal Injuries



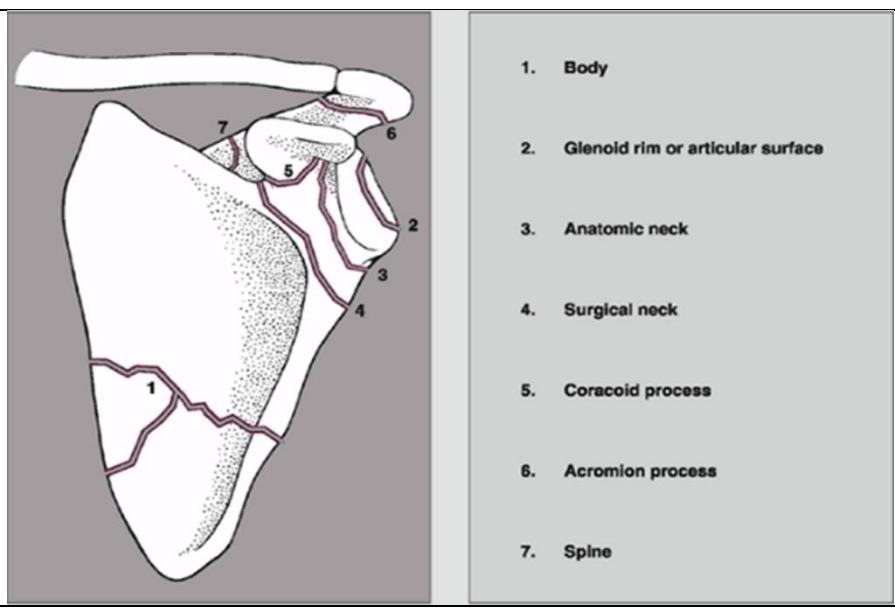
Type I: separation
Type II: a fragment from the metaphysis accompanies the displaced epiphysis
Type III: a vertical fracture through the epiphysis and along the growth plate
Type IV: a vertically orientated fracture through the epiphysis, growth plate into the metaphysis
Type V: crushing of the growth plate

❖ Clavicle Fracture Classification

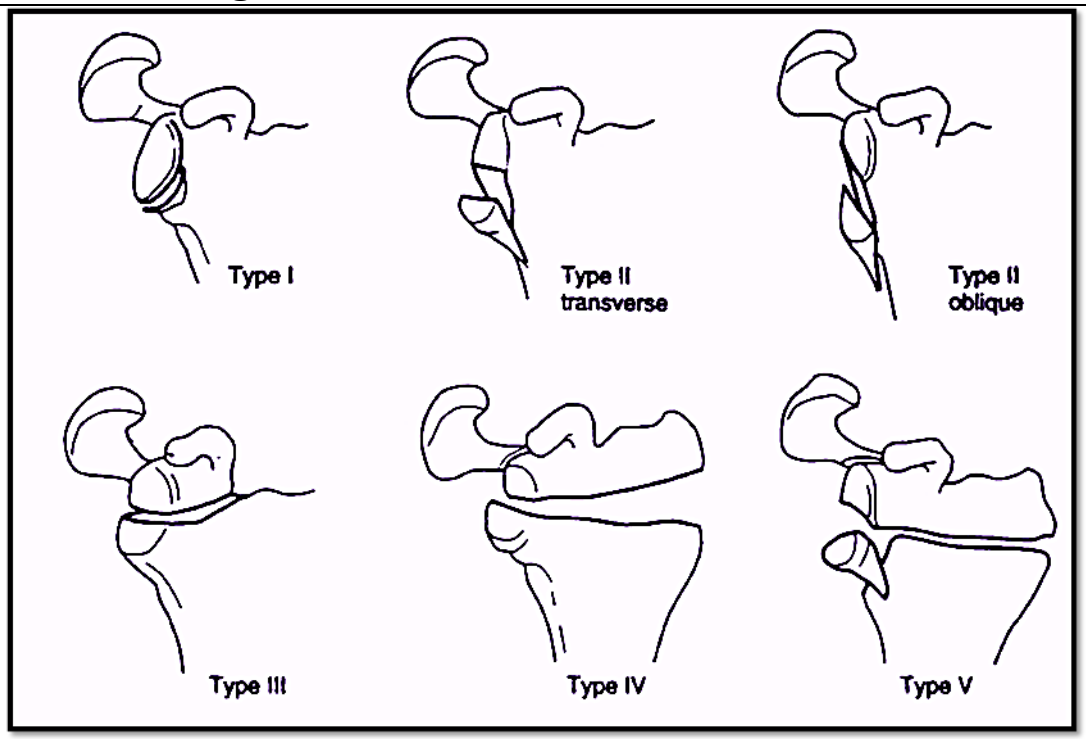



B. Neer Classification of Fractures of the Distal Clavicle
1
2
3
1. Nondisplaced fracture, intact ligaments
2. Displaced interligamentous fracture; conoid ligament torn, trapezoid ligament remains attached to the distal segment
3. Fracture extends to articular surface, ligaments intact

❖ Scapular Fracture Classification



❖ Ideberg Classification of Glenoid Fractures

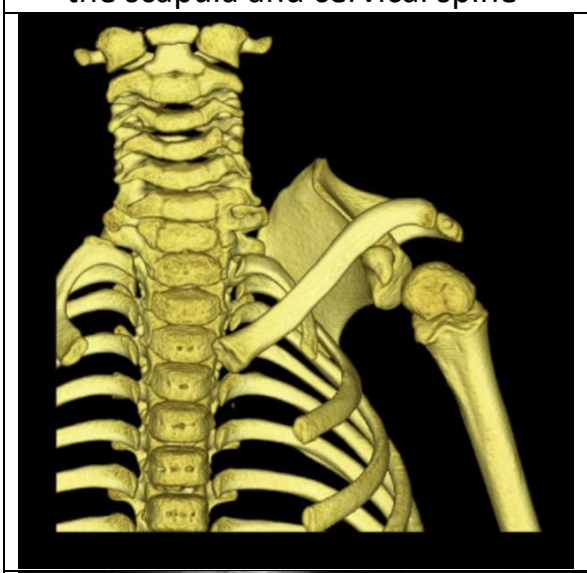


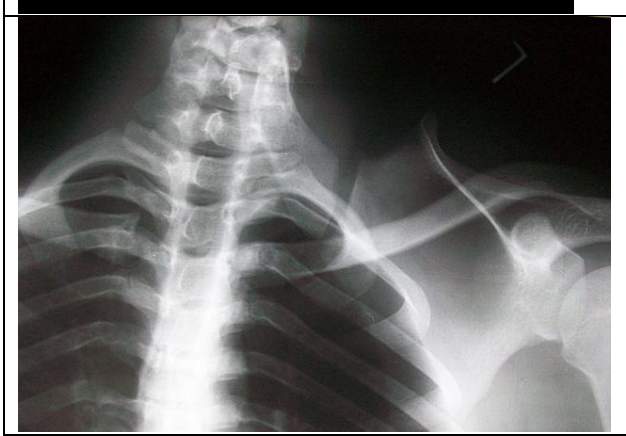
Sprengel Shoulder Deformity

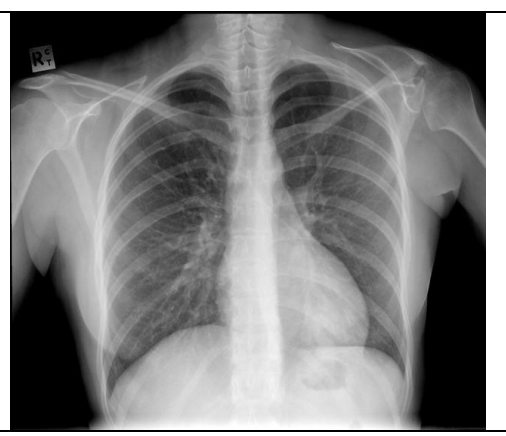
- Most common congenital shoulder abnormality.
- Failure of normal descent of scapula from initial mid-cervical position to final thoracic position.

Imaging Findings:

- Scapula is elevated
- Scapula is dysplastic, appearing smaller in the horizontal plane and larger in the vertical plane
- Scapula is rotated, with the inferior angle directed medially towards spine.
- Omovertebral bar (fibrous, cartilaginous and/or osseous connection) between the scapula and cervical spine







❖Klippel-Feil Syndrome

Classic clinical triad:

- Short neck, Low hairline, Restricted neck motion

Imaging Findings:

- **Vertebral fusion:** fused facets and spinous processes
- Anteroposterior narrowing of the vertebral bodies (wasp-waist sign)
- Hemivertebrae
- Omovertebral bone
- Spina bifida

Associated:

- **Scoliosis and Sprengel Deformity**

MR imaging can also reveal associated conditions such as:

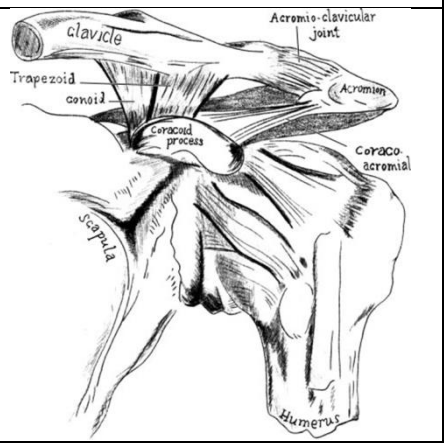
- Syringohydromyelia, Diastematomyelia, Diplomyelia
- Chiari I Malformation

Acromioclavicular Joint

- The ACJ is a plane synovial joint between the lateral surface of the clavicle and the medial surface of the acromion.

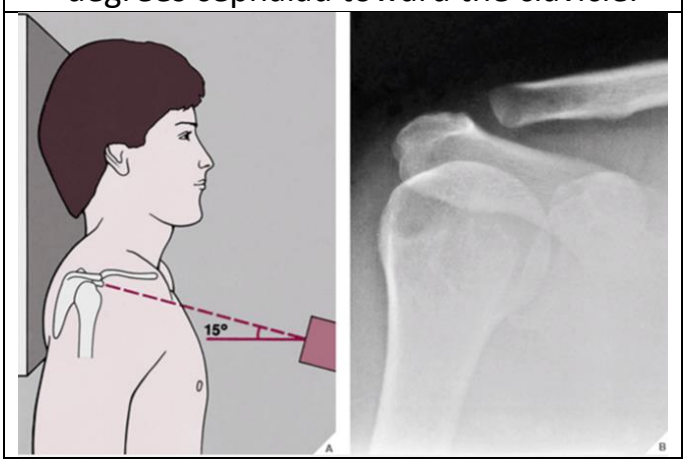
Main stabilizer of ACJ

- Superior and inferior acromioclavicular ligaments:
  - Strengthen joint capsule
- Coracoclavicular ligament: 2 parts form V-shape:
  - Conoid ligament medially
  - Trapezoid ligament laterally
- Coracoacromial ligament.

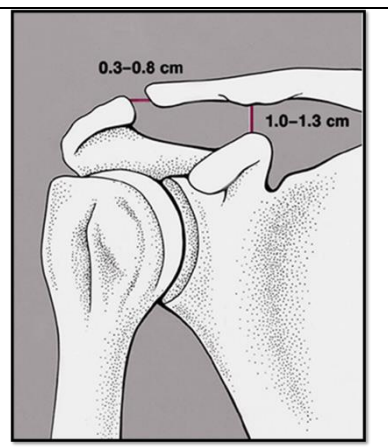


❖ Acromioclavicular view:

- Patient is erect, with the arm of the affected side in the neutral position.
- The central beam is directed 15 degrees cephalad toward the clavicle.

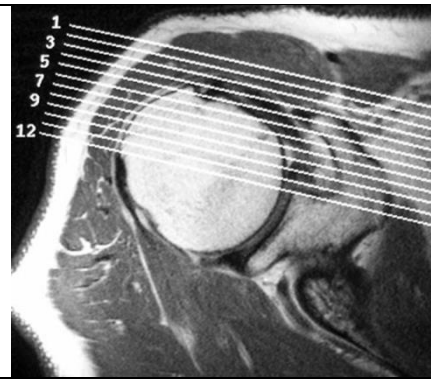


❖ Normal Measurements

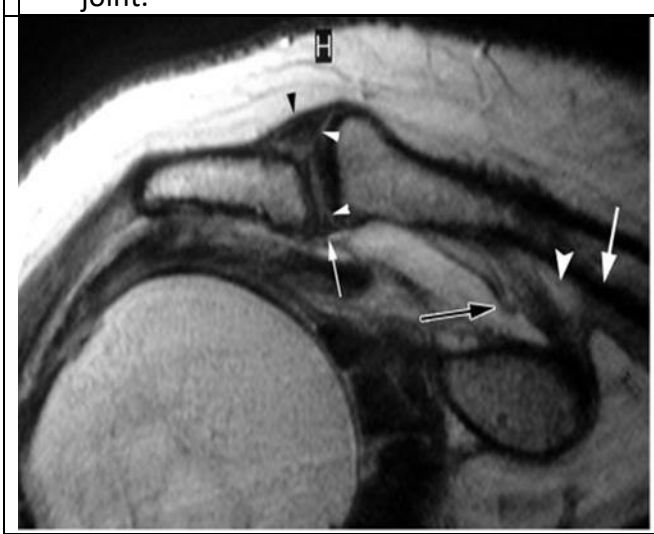


❖MRI Imaging Technique

- Axial T1-weighted spin-echo (SE) scout image shows the plane in which the Coronal images are obtained: parallel to a line drawn from the coracoid process to the lesser tuberosity.



Coronal Images	Sagittal Images:
• Conoid (large white arrow) and trapezoid (black arrow) portions of the coracoclavicular ligament. • Fat is seen between these ligaments (large white arrowhead). • The superior (black arrowhead) and inferior (small white arrow) acromioclavicular ligaments • Intraarticular fibrocartilaginous disk (small white arrowheads) are has the same signal intensity as the hyaline cartilage lining the joint.	• Conoid component of the coracoclavicular ligament (arrowhead).



❖ Rockwood System Based On Plain Film Findings

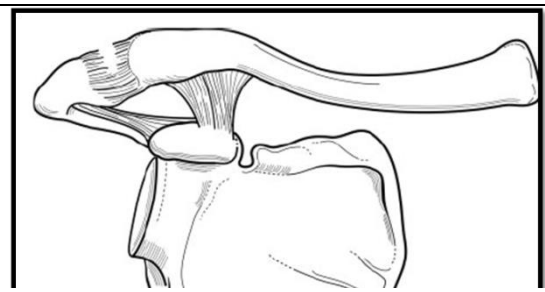
- Type I: Radiographs are normal.
- Type II: Radiographs demonstrate subluxation of the acromioclavicular joint (measuring less than 1 cm), without any abnormality of the coracoclavicular space.
- Type III: Radiographs demonstrate further subluxation of the AC joint (now measuring more than 1 cm), displacement of the clavicle and widening of the coracoclavicular space.
- Type IV: Radiographs again demonstrate subluxation of the AC joint (measuring greater than 1 cm), widening of the coracoclavicular space, and posterior displacement of the clavicle. This injury is sometimes also called anterior dislocation of the scapula because the scapula is pushed anteroinferiorly.
- Type V: Radiographs are similar to that of a Type IV injury, except the clavicle is displaced superiorly.
- Type VI: Radiographs are similar to that of a Type IV injury, except the clavicle is displaced inferior to the coracoid process or acromion. This injury is rare.

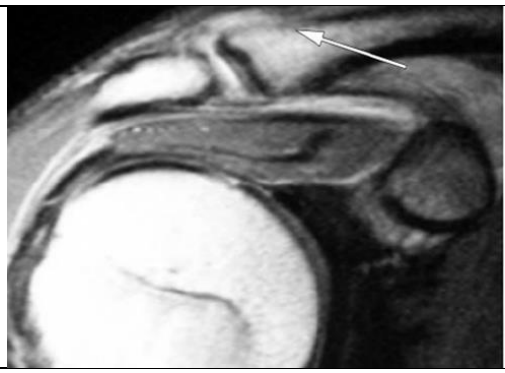
❖ Modified Rockwood System To Include MR Findings

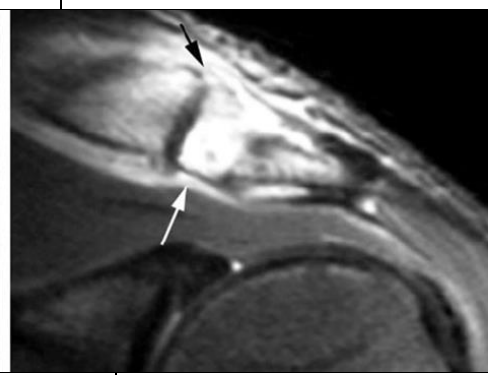
- Type I: No specific abnormal MR findings are seen.
- Type II: Rupture of the acromioclavicular ligament, coracoclavicular ligament edema (but intact fibers) and marrow edema in the clavicle and acromion is seen.
- Type III: The coracoclavicular ligament is now completely ruptured and hemorrhage is seen in the coracoclavicular space.

Grade 1 Injury

- An incomplete tear of the superior (dorsal) acromioclavicular ligament.
- AC ligament : mild sprain
- CC ligament : intact
- Joint capsule : intact
- Clavicle not elevated with respect to acromion
- AC distance: Normal
- CC distance: Normal

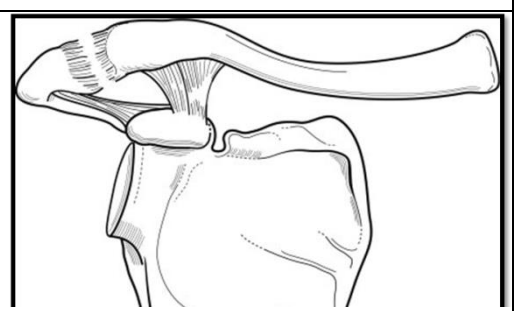


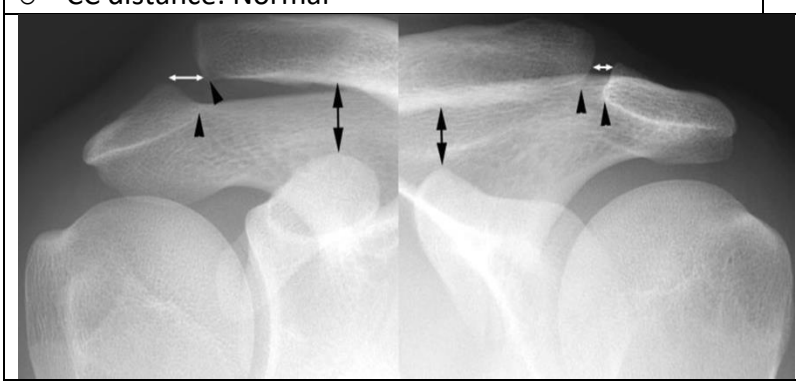


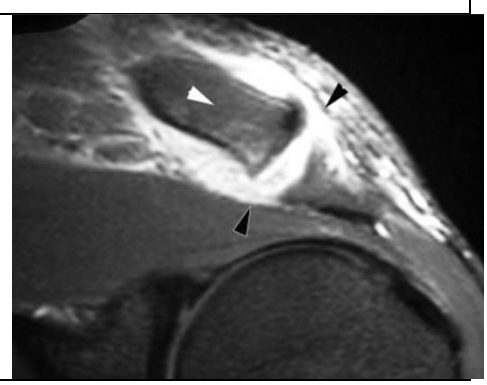


Grade 2 Injury

- AC ligament: Complete tear
- CC ligament: sprain
- Joint capsule: ruptured
- Deltoid muscle : minimally detached
- Trapezius muscle : minimally detached
- Clavicle elevated but not above superior border of acromion
- AC distance: Widened
- CC distance: Normal

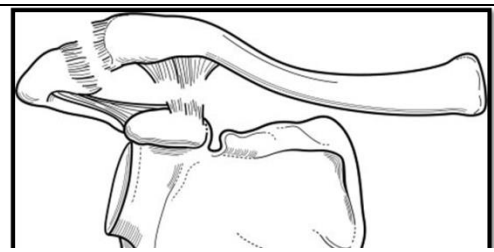


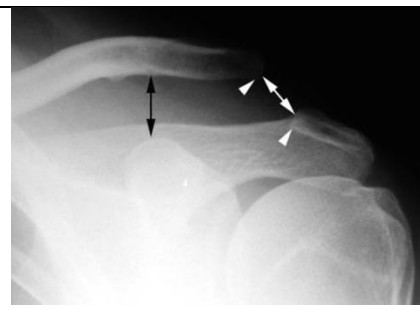




Grade 3 Injury

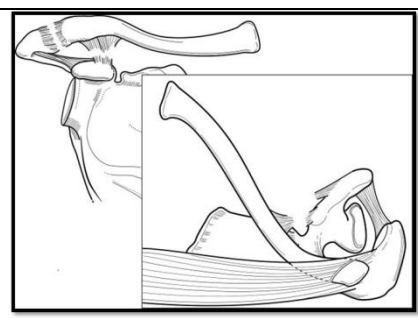
- AC ligament : Torn
- CC ligament : Torn
- Joint capsule : ruptured
- Deltoid muscle : detached
- Trapezius muscle : detached
- Clavicle elevated above superior border of acromion
- AC distance: Widened
- CC distance: Widened but less than twice normal

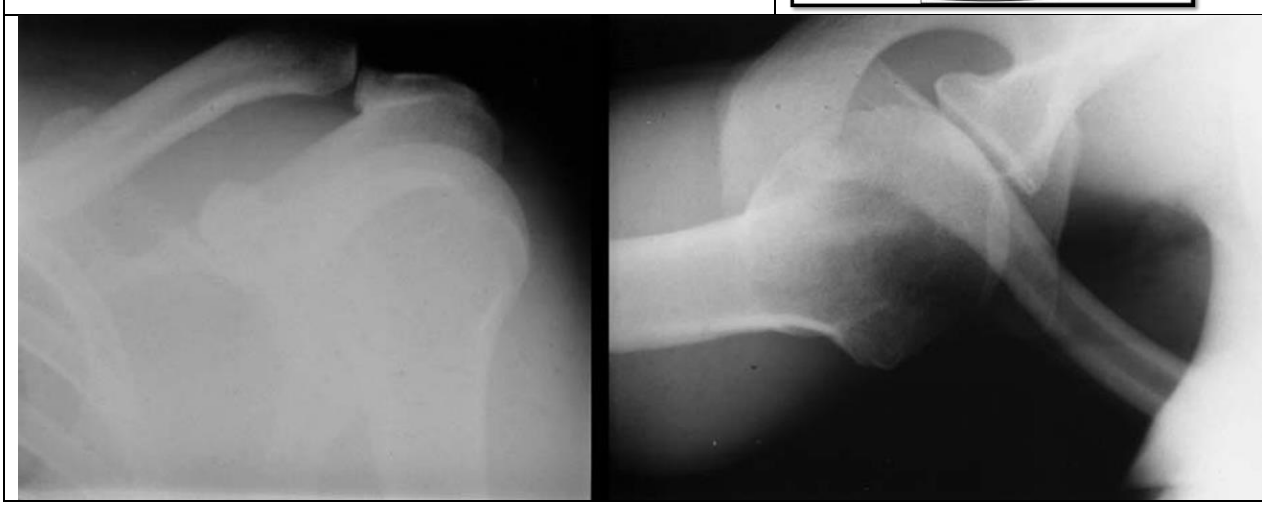




Grade 4 Injury

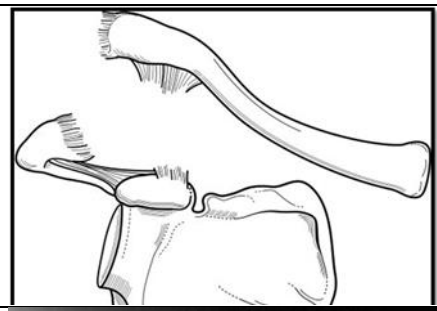
- AC ligament : Torn
- CC ligament : Torn
- Joint capsule : ruptured
- Deltoid muscle : detached
- Trapezius muscle : detached
- Clavicle displaced posteriorly into trapezius

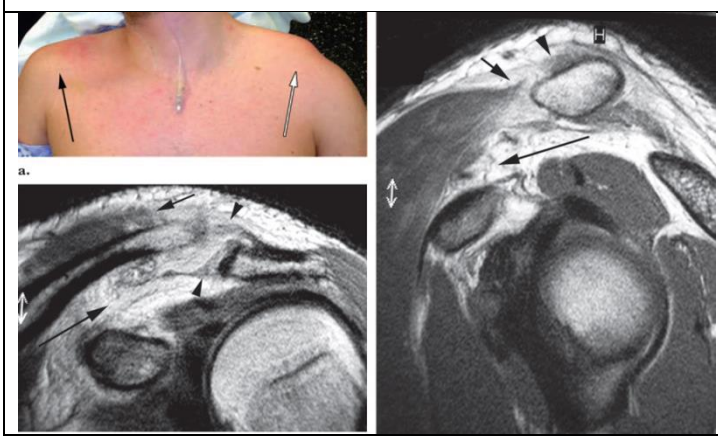


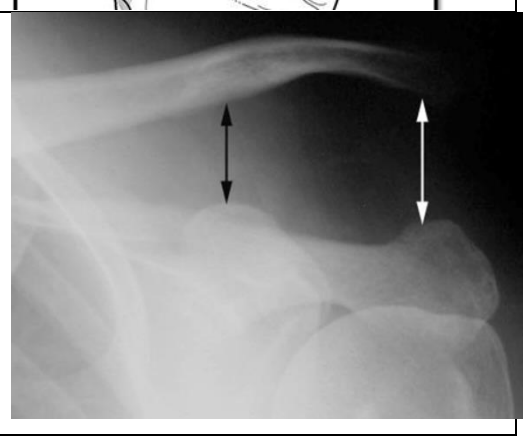


Grade 5 Injury

- AC ligament: Torn
- CC ligament: Torn
- Joint capsule : ruptured
- Deltoid muscle : detached
- Trapezius muscle : detached
- Clavicle is markedly elevated
- CC distance > double normal (e.g. >25mm)



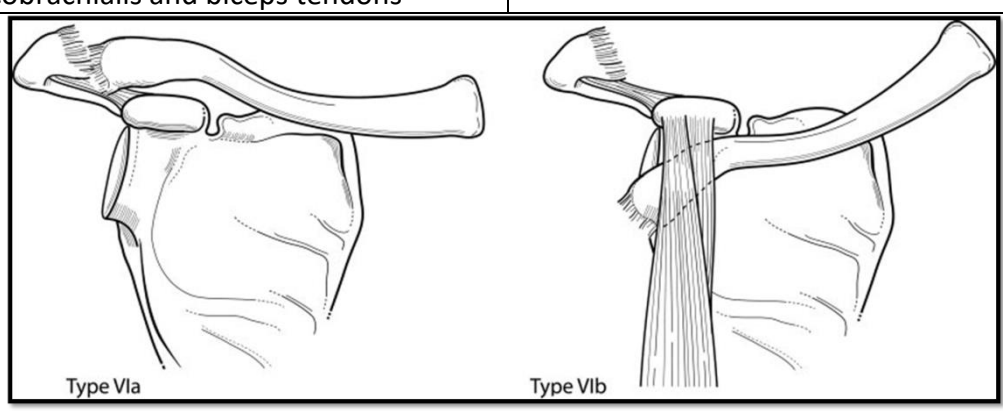




Grade 6 Injury

- Rare
- AC ligament : Torn
- CC ligament : Torn
- Joint capsule : ruptured
- Deltoid muscle : detached
- Trapezius muscle : detached
- Clavicle inferiorly displaced behind coracobrachialis and biceps tendons

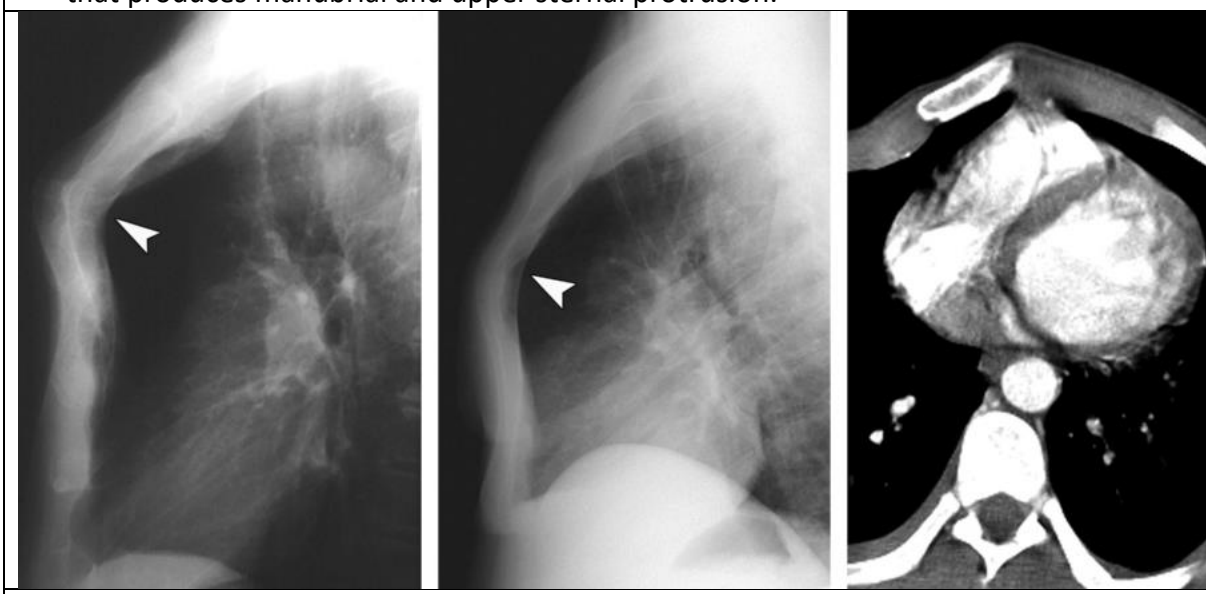
- Type 6a injury results in inferior subluxation of the clavicle relative to the acromion along with tears of the acromioclavicular ligaments.
- Type 6b injury results in subcoracoid dislocation of the clavicle as well as tears of the coracoclavicular ligaments.



Sternum and Sternoclavicular Joint

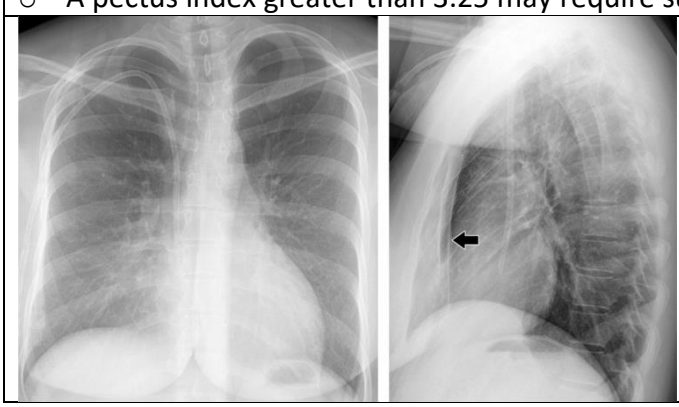
❖ Pectus Carinatum = Pigeon Breast

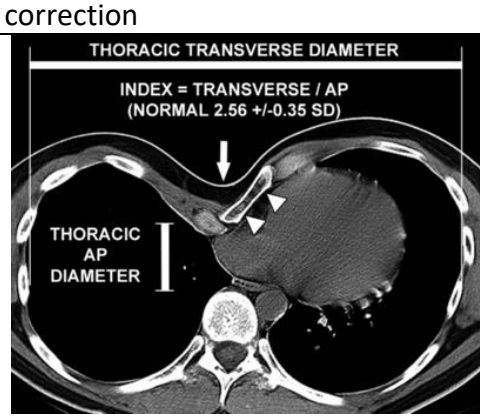
- The sternum is displaced anteriorly.
- Two different types of pectus carinatum deformity, with different surgical implications, have been identified.
- The more common is a chondrogladiolar deformity that results in protrusion of the middle and lower sternum.
- The less common variant is a chondromanubrial deformity (Currarino-Silverman syndrome) that produces manubrial and upper sternal protrusion.



❖ Pectus Excavatum

- Is the most common congenital deformity of the sternum.
- most occurrences are isolated
- may occur in association with Marfan syndrome, Ehlers-Danlos syndrome, Poland syndrome, and congenital heart disease.
- The pectus index can be calculated from axial CT or MR imaging data by dividing the transverse diameter of the chest by the anteroposterior diameter
- The normal value of this index is 2.56 (standard deviation, 0.35).
- A pectus index greater than 3.25 may require surgical correction

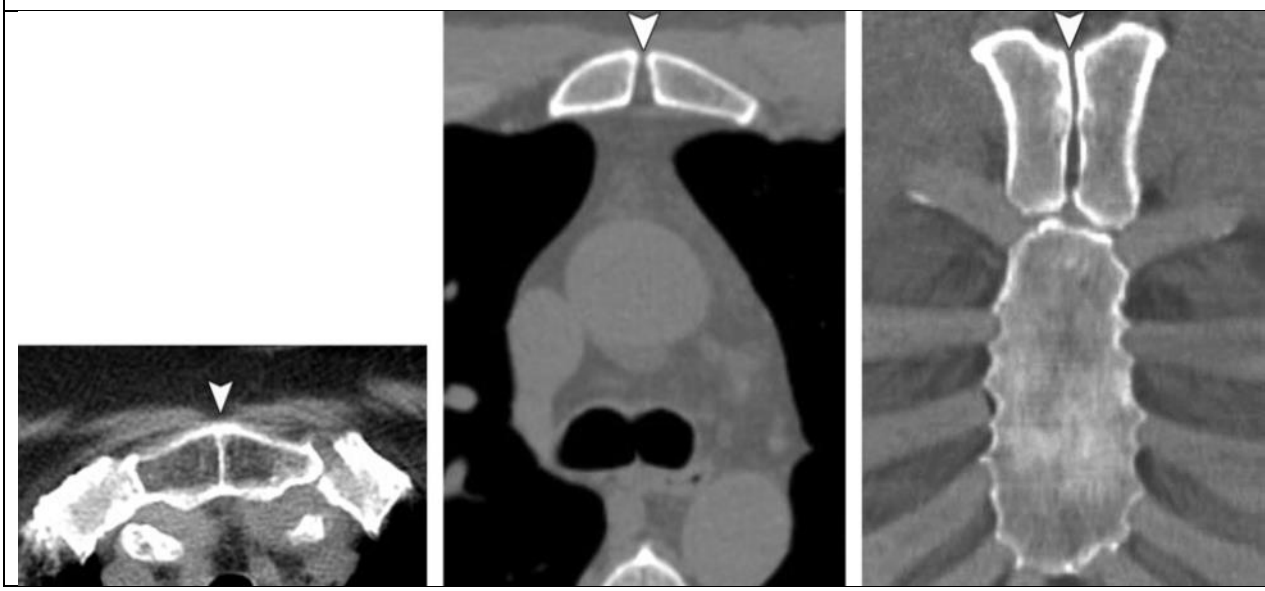




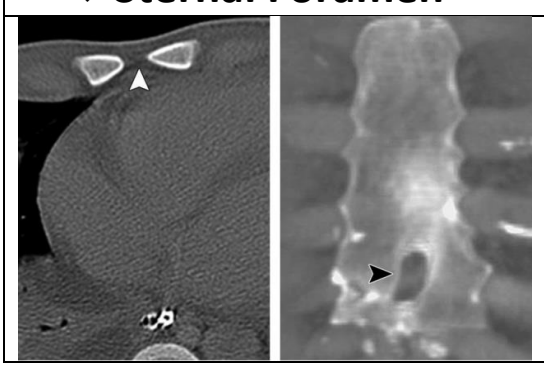
❖ Tilted Sternum

- The term tilted sternum refers to a sternum that is not oriented in the horizontal left-to-right axis of the body but instead is oriented obliquely.
- The asymmetric orientation produces a unilateral irregularity of the chest wall that may be mistaken for a chest wall tumor at physical examination.

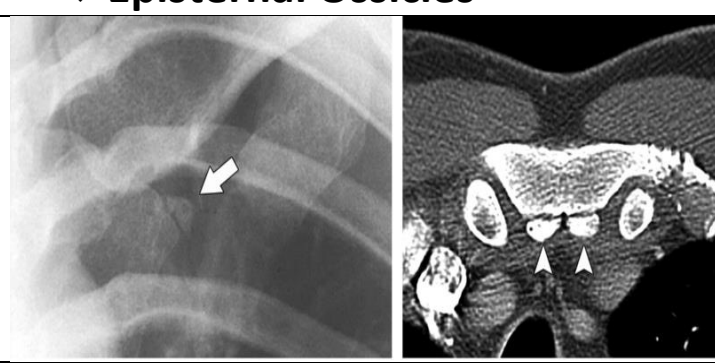
❖ Sternal Sclerotic Band and Cleft



❖ Sternal Foramen

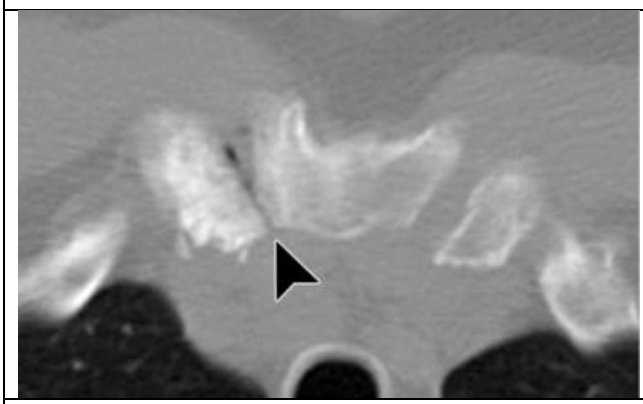
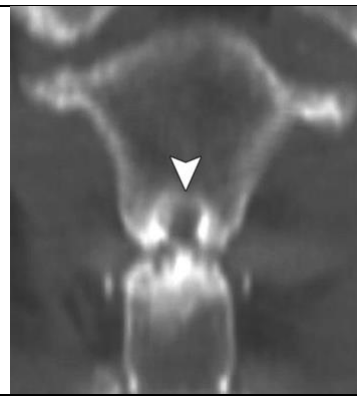


❖ Episternal Ossicles



❖Osteoarthritis

- Degenerative disease
- Joint space narrowing
- Subchondral sclerosis and subchondral cysts
- Osteophyte formation
- Changes of the fibrocartilaginous disk

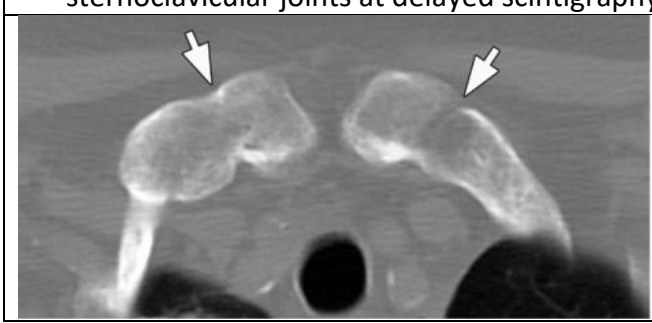
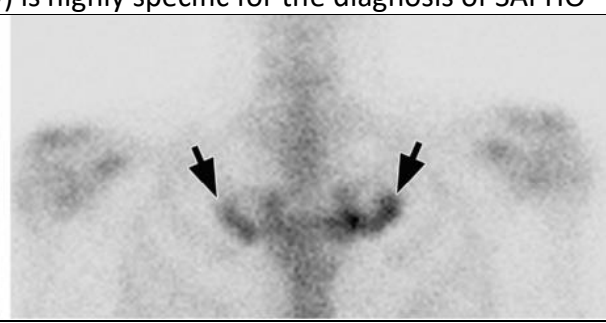
Sternoclavicular Joint	Manubriosternal Joint
	

❖Seronegative Arthritis

- Erosions and partial or complete fusion of the manubriosternal joint
- Ankylosing spondylitis, reactive arthritis (Reiter syndrome), and psoriatic arthritis

❖SAPHO

- (Synovitis, acne, palmoplantar pustulosis, hyperostosis, and osteitis),
- A wide spectrum of aseptic neutrophilic dermatoses in association with aseptic osteoarticular lesions.
- Hyperostosis and osteosclerosis are characteristic findings
- Joint erosion and ankyloses
- The “bull’s head” sign (ie, increased radiotracer uptake in the sternal manubrium and both sternoclavicular joints at delayed scintigraphy) is highly specific for the diagnosis of SAPHO

❖Osteomyelitis

Primary osteomyelitis of the sternum:

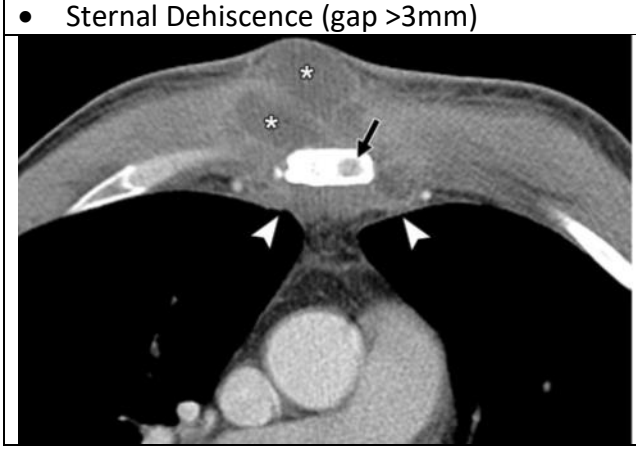
- Uncommon
- Risk Factors:
  - Patients with a history of intravenous drug abuse
  - Acquired immunodeficiency syndrome
  - Hemoglobinopathy
  - Other immune deficiency states
- Causative organism:
  - Staphylococcus aureus infection is the most common cause of sternal osteomyelitis
  - Salmonella species (in patients with sickle cell disease)
  - Pseudomonas aeruginosa (among intravenous drug abusers)
  - Candida albicans, Aspergillus fumigatus, and Mycobacterium tuberculosis, have been reported

Secondary osteomyelitis

- More common than the primary form
- Risk factors:
  - Sternotomy
  - Obesity, insulin-dependent diabetes,
  - Internal mammary artery grafts
- Causative organism:
  - Gram-positive cocci (ie, S aureus)
  - Gram-negative bacilli (such as Pseudomonas, Serratia, and Klebsiella species)

Imaging Findings:

- Bone/medullary
  - X-ray: Osteopenia – Lytic destructive lesion
  - MRI: Low T1/High STIR
  - Scintigraphy: increased radiotracer uptake
- Cortical disruption and periosteal reaction
- Soft tissue swelling, small fluid loculations with inflammatory changes in parasternal region
- Sternal Dehiscence (gap >3mm)



❖Septic Arthritis

- Uncommon infectious condition
- Monoarticular
- Causative organism: S aureus and P aeruginosa

Complications include:

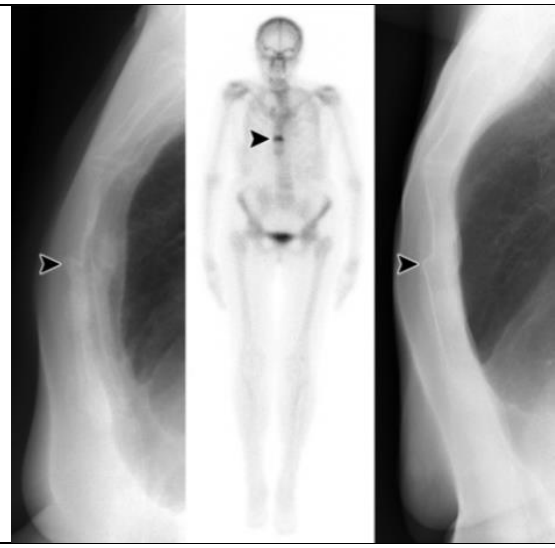
- Sternal osteomyelitis occurs in 50% of cases
- Abscesses occur in about 20% of cases.
- Mediastinitis
- Superior vena cava syndrome
- Septic shock.

Imaging Findings:

- Destruction of the articular surface
- Widening of the joint space
- Chest wall phlegmon
- Gas and fluid collections in the chest wall and mediastinum.
- Mediastinal soft tissue stranding

❖Sternal Fractures

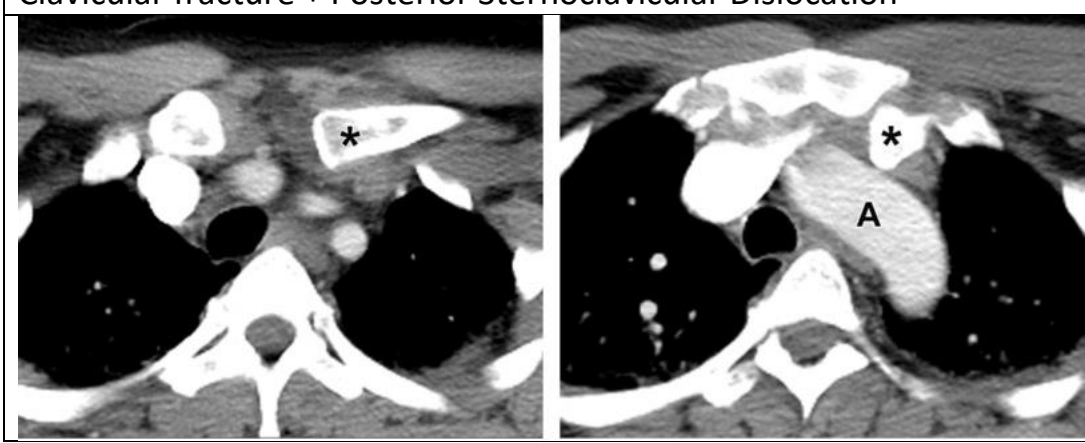
- High-energy trauma
    - Associated injuries such as fractured ribs, pulmonary and cardiac trauma, craniocerebral injuries, thoracic and lumbar spinal fractures, whiplash, and lower extremity injuries
- Pathological fracture: Neoplasm (eg, multiple myeloma, metastasis)
- Strain from heavy lifting and labor
- Insufficiency fracture (eg, in osteoporosis)



❖Sternoclavicular Dislocation

- Anterior (or presternal) displacement is more common
- Posterior (or retrosternal) displacement is more frequently associated with life-threatening complications caused by the compression of vital structures such as the trachea, great vessels, and nerves

Clavicular fracture + Posterior Sternoclavicular Dislocation

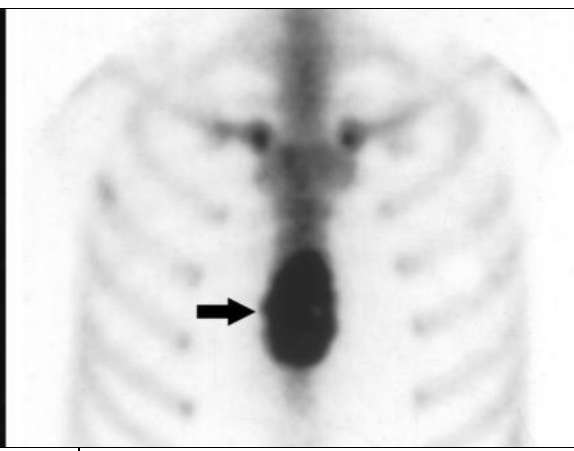


❖Sternal Neoplasms

Sternal Metastases

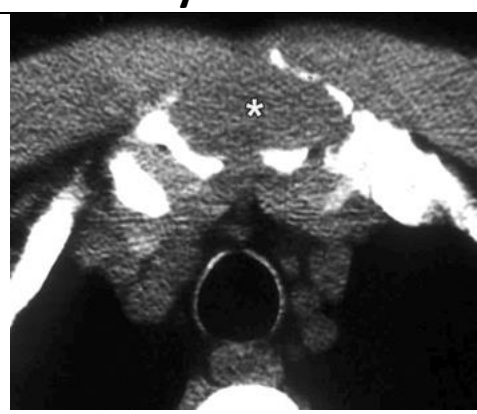
Lytic	Sclerotic

Ewing Sarcoma



Chondrosarcoma

Plasmacytoma



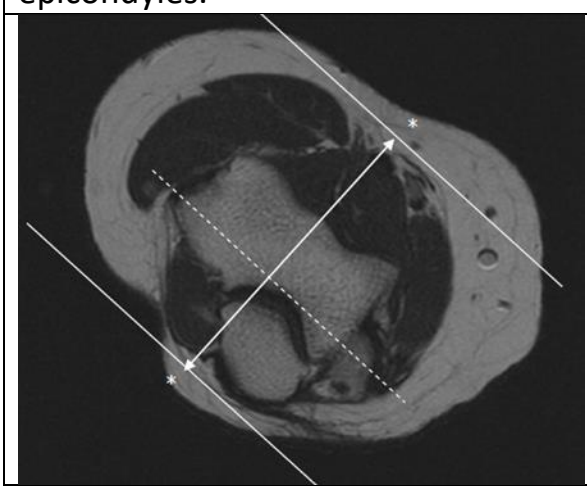
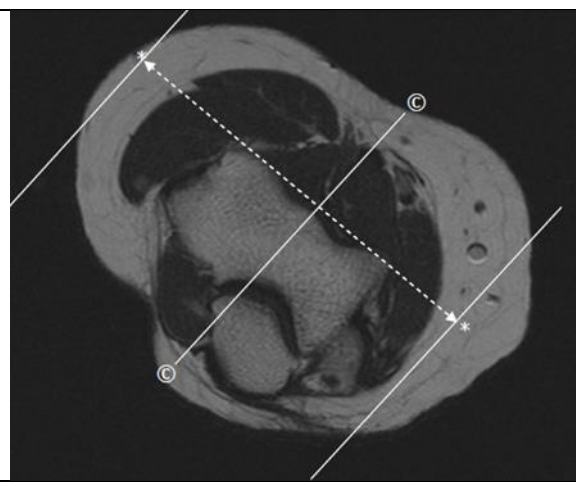
Elbow Joint

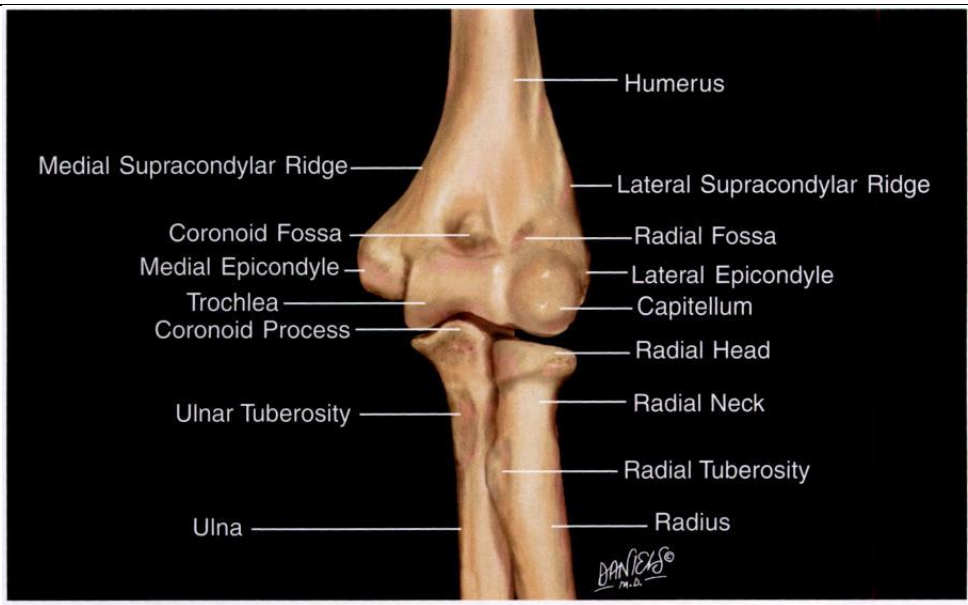
❖ Anatomy

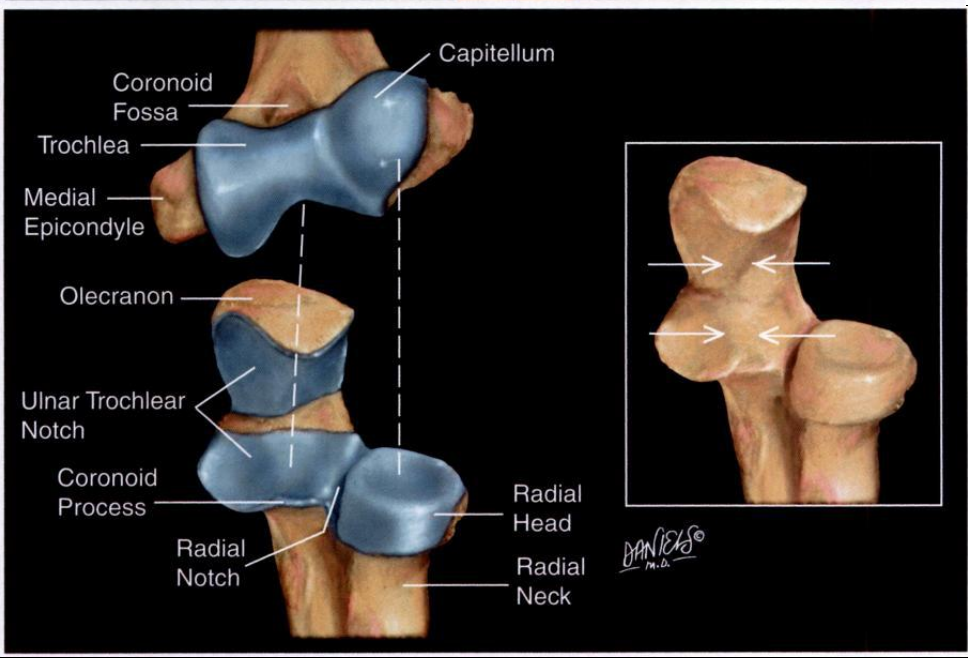
- Synovial Joint hinge variety
  - Ulno-humeral
  - Radio-capitellar
  - Proximal radio-ulnar

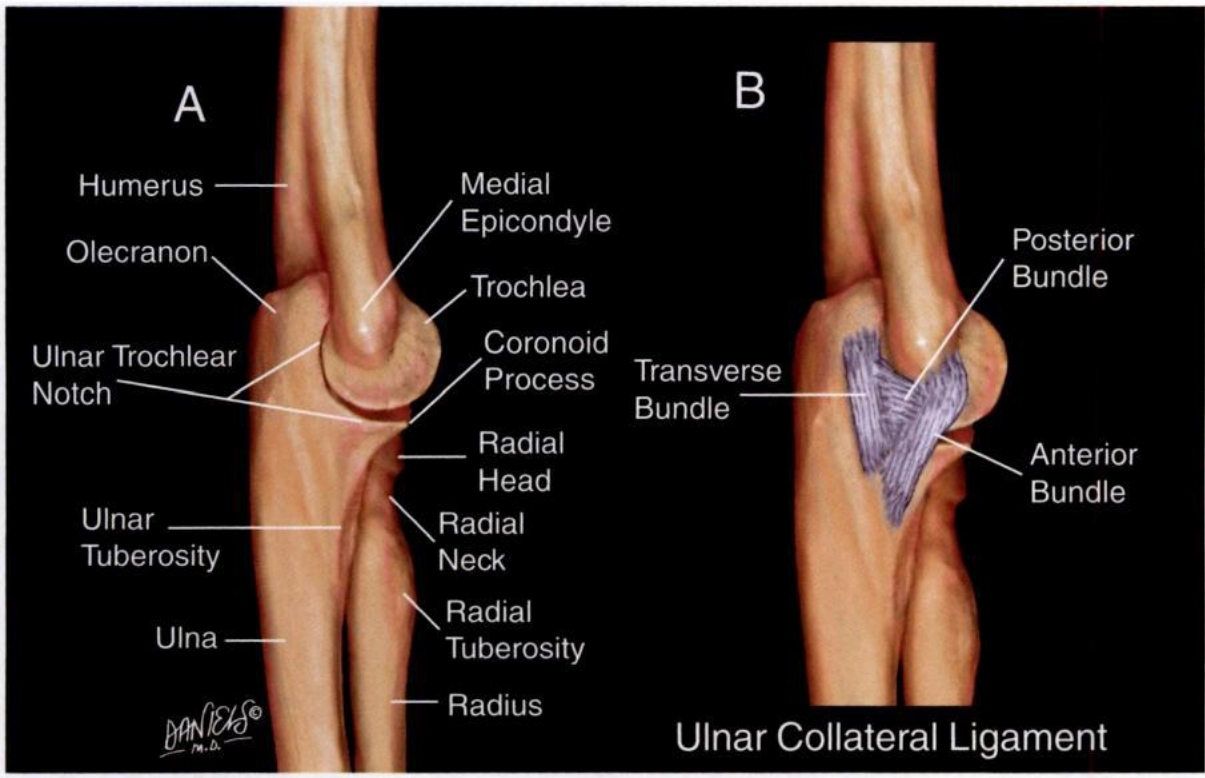
MRI Technique:

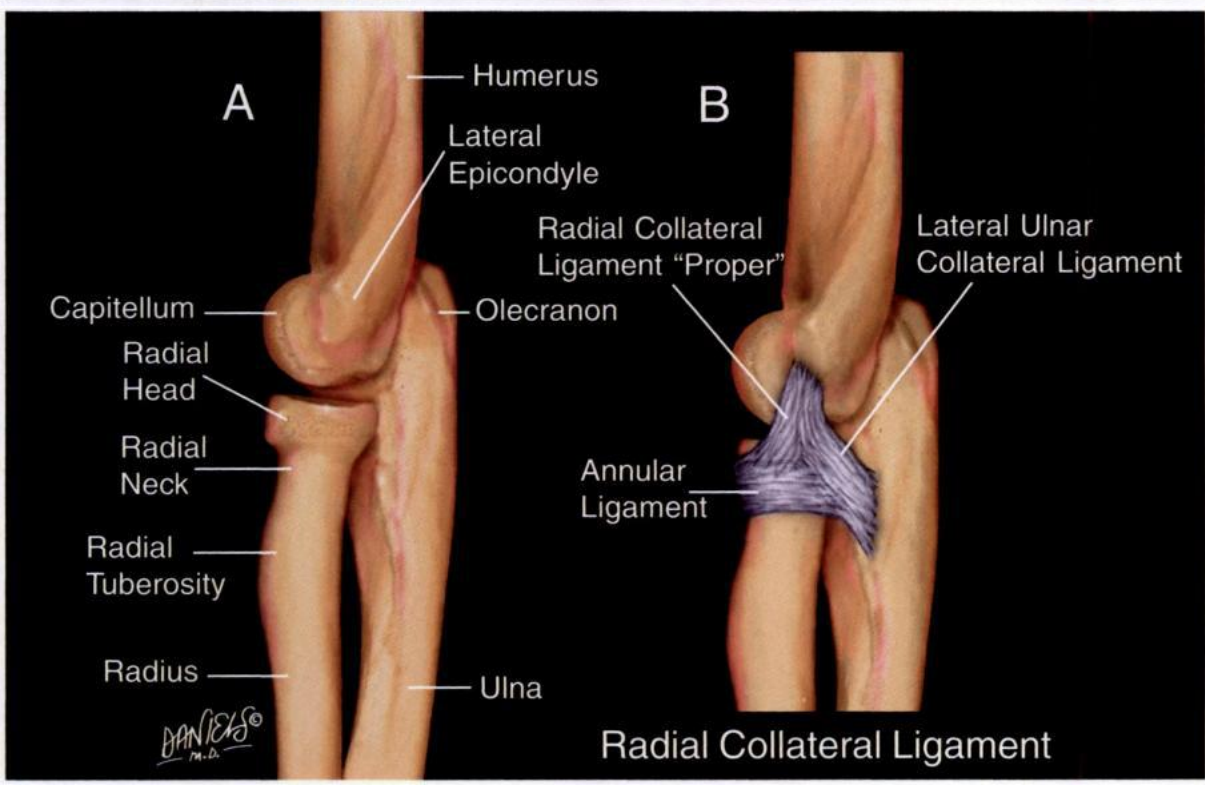
- Patient position:(Supine, elbow at side)
- Coil selection: surface coil.
- Pulse Sequences:
  - Coronal T1 & STIR/T2 FS & GRE T2*
  - Sagittal T1 & STIR
  - Axial T1 & STIR/T2 FS
  - FABS for biceps tendon

Coronal Imaging Plane	Sagittal Imaging Plane
Plane parallel to medial and lateral epicondyles.	Plane perpendicular to coronal plane
	

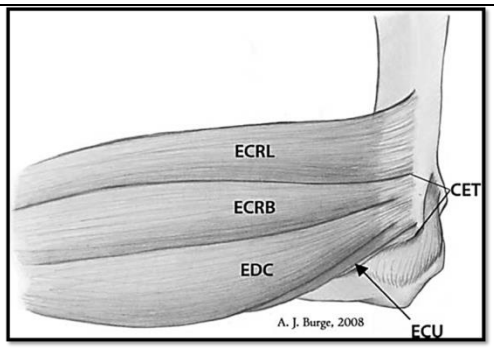

Humerus
Medial Supracondylar Ridge
Lateral Supracondylar Ridge
Coronoid Fossa
Radial Fossa
Medial Epicondyle
Lateral Epicondyle
Trochlea
Capitellum
Coronoid Process
Radial Head
Ulnar Tuberosity
Radial Neck
Radial Tuberosity
Ulna
Radius


Capitellum
Coronoid Fossa
Trochlea
Medial Epicondyle
Olecranon
Ulnar Trochlear Notch
Coronoid Process
Radial Head
Radial Notch
Radial Neck


A
Humerus
Medial Epicondyle
Olecranon
Trochlea
Ulnar Trochlear Notch
Coronoid Process
Radial Head
Ulnar Tuberosity
Radial Neck
Radial Tuberosity
Ulna
Radius
B
Posterior Bundle
Transverse Bundle
Anterior Bundle
Ulnar Collateral Ligament

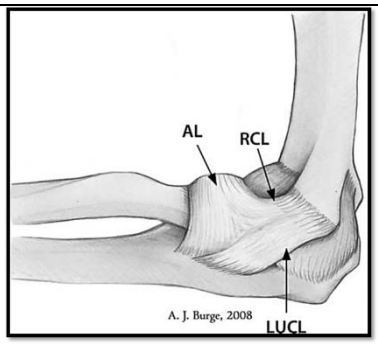

A
Humerus
Lateral Epicondyle
Capitellum
Olecranon
Radial Head
Radial Neck
Radial Tuberosity
Radius
Ulna
B
Radial Collateral Ligament "Proper"
Lateral Ulnar Collateral Ligament
Annular Ligament
Radial Collateral Ligament

❖ Lateral Elbow Musculotendinous Anatomy

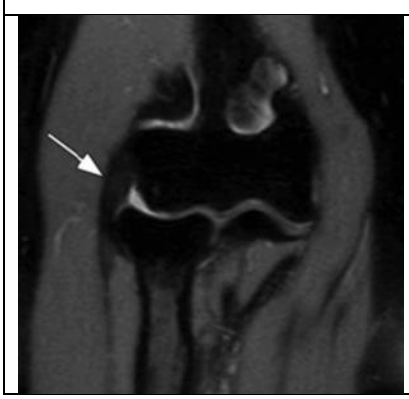


Tendon origin on the lateral epicondyle.
CET = common extensor tendon
ECRB = extensor carpi radialis brevis
ECRL = extensor carpi radialis longus
ECU = extensor carpi ulnaris
EDC = extensor digitorum communis

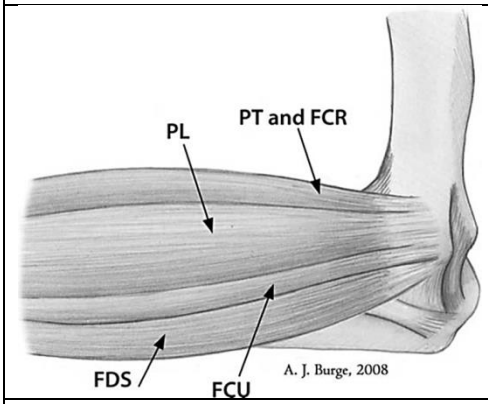
❖ Lateral Collateral Ligament Complex



Annular ligament.
Accessory lateral collateral ligament
LUCL= lateral ulnar collateral ligament
RCL = radial collateral ligament.

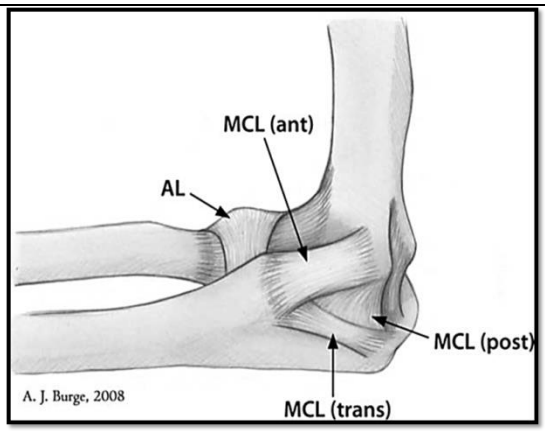
Common Extensor Origin	RCL	LUCL **Posterior to the radial head**
		

❖ Medial Elbow Musculotendinous Anatomy



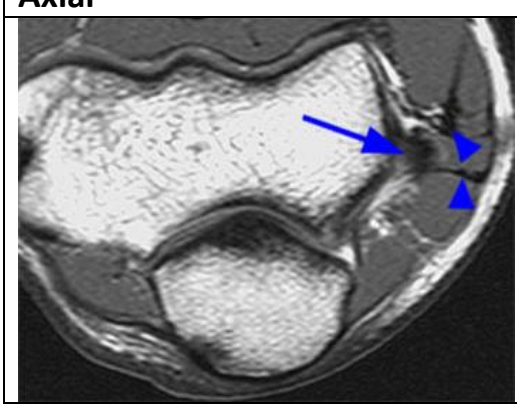
<u>Common Flexor Origin:</u>
FCR = flexor carpi radialis
FCU = flexor carpi ulnaris
FDS = flexor digitorum superficialis
PL = palmaris longus
PT = pronator teres

❖ Medial Elbow Ligamentous Anatomy



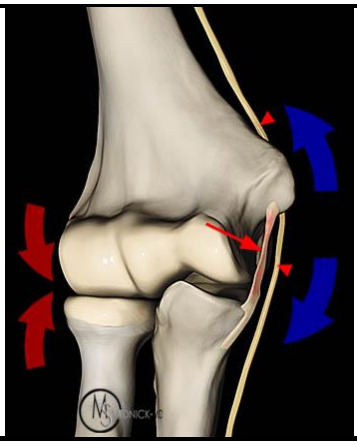
AL = annular ligament
MCL = medial collateral ligament = Ulnar collateral ligament
Ant = anterior band
Post = posterior band
Trans = transverse band

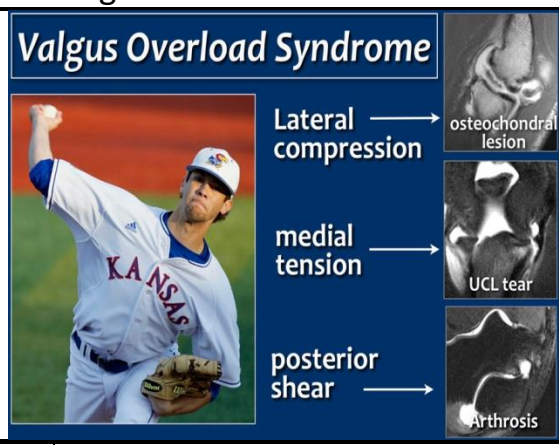
MCL = UCL (arrows)
Common flexor tendon (arrow head)
Anteromedial aspect of the medial epicondyle

Axial	**Coronal GRE**	**Coronal T1**
		

❖Valgus Overload Syndrome

- Tension on the medial side => tear of ulnar collateral ligament.
- Compression on the lateral side => osteochondral lesion of the capitellum.
- Shear forces on the posterior side => arthrosis.
- The ulnar nerve is also at risk for stretching or traction





Marrow edema deep to distal attachment at the sublime tubercle (arrowhead).
Intact UCL

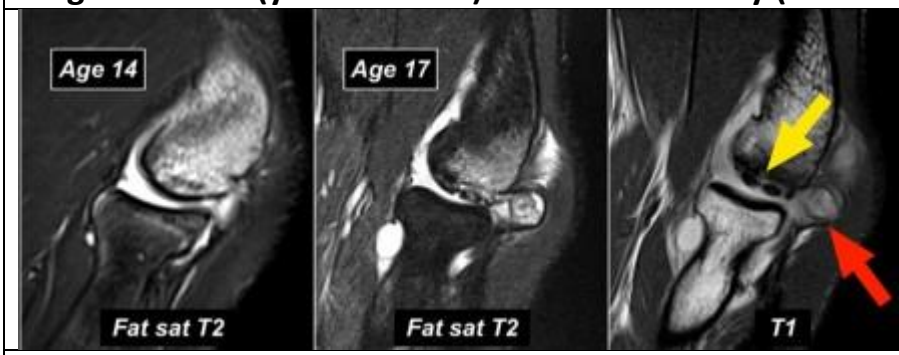
Edema and laxity along the course of the anterior bundle of the UCL (red arrow)
Edema within the capitellum (arrowheads)

Proximal tear of anterior bundle of the UCL (arrow).

Distal tear of the anterior bundle of the UCL. (arrow)

Osteochondral Lesion of Capitellum

Fragmentation (yellow arrow) with a loose body (red arrow).



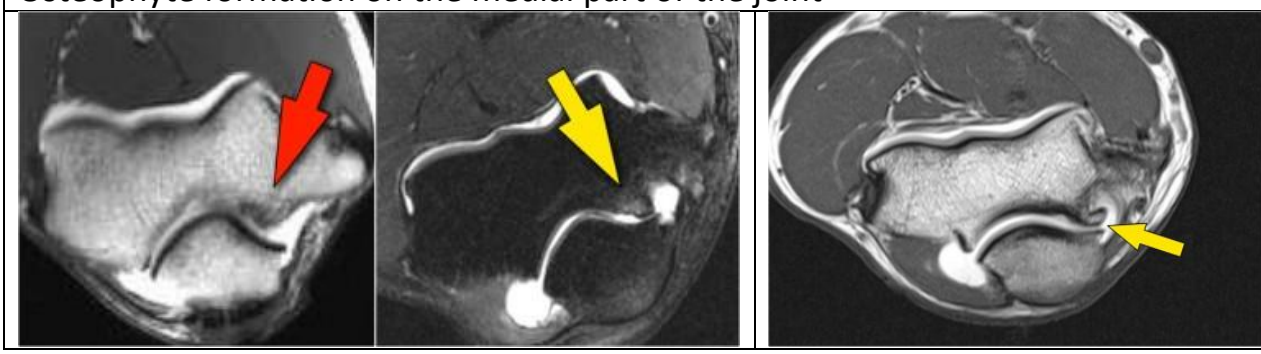
Arthrosis in valgus overload syndrome

Due to the valgus overload there are shear forces on the posteromedial part of the humeroulnar joint.

T1: Subchondral sclerosis seen on T1W-image (red arrow).

T2: Subchondral bone marrow edema and cartilage loss (yellow arrow).

Osteophyte formation on the medial part of the joint



❖Epicondlytis

- 4th and 5th decades of life
- Lateral >>> Medial (10 times)
- Epicondylitis represents a degenerative process involving the origin of:
  - Extensor tendons at the lateral elbow
  - Flexor-pronator muscle group at the medial elbow.

Aetiology:

- Repetitive stress and overuse lead to tendinosis with microtrauma => partial tearing => full-thickness tendon tear

Tendinosis:

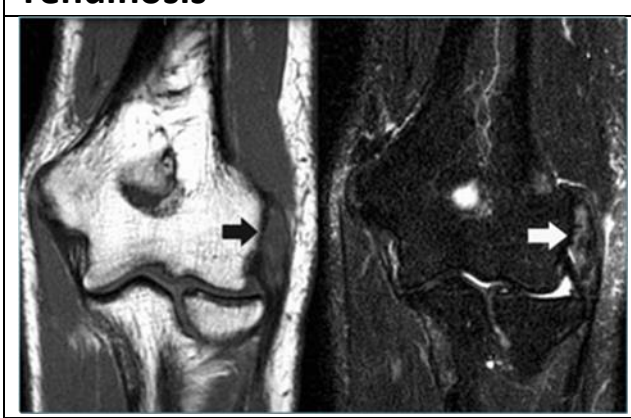
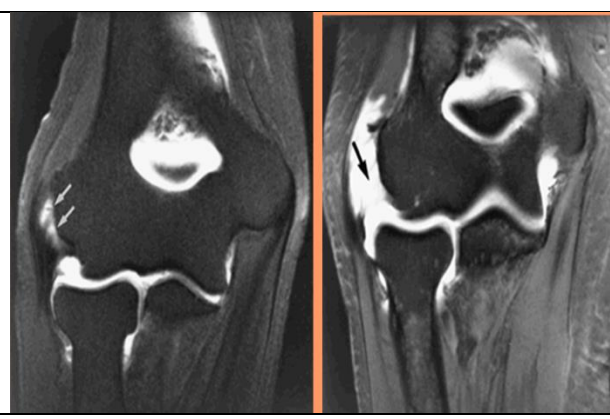
- Intratendinous thickening
- Increased T2/STIR signal intensity

Tendon tear:

- fluid-signal-intensity gap between the tendon and the epicondyle
- Interdigitation of fluid with the tendon or muscle fibers.

A. Lateral Epicondylitis = Tennis Elbow:

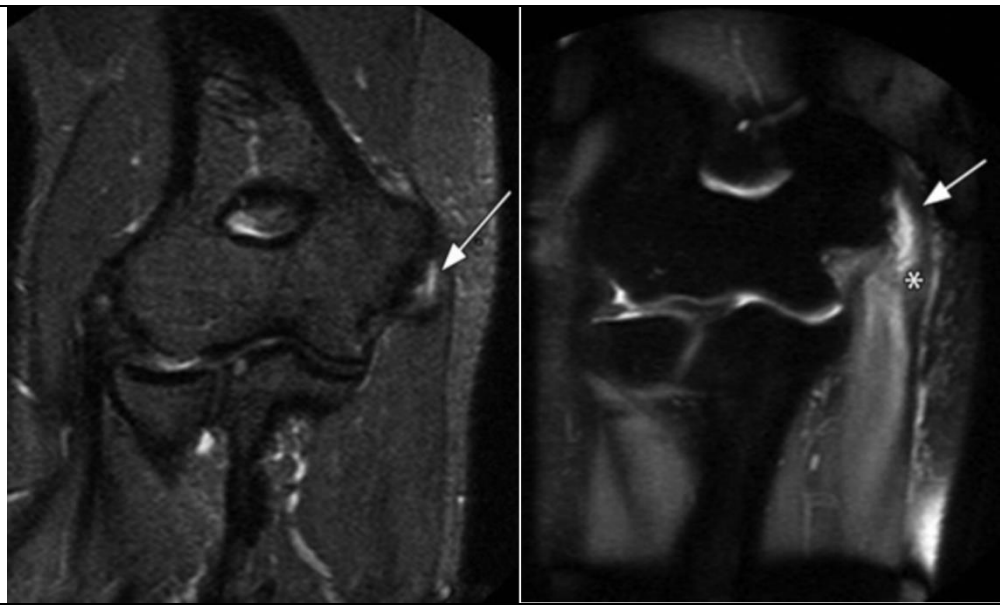
- "The most frequent soft tissue abnormality affecting the elbow joint".
- Lateral epicondylitis is an overuse syndrome, caused by repeated microtrauma to the origin of the common extensor tendon.

Tendinosis	Tendon tear
	

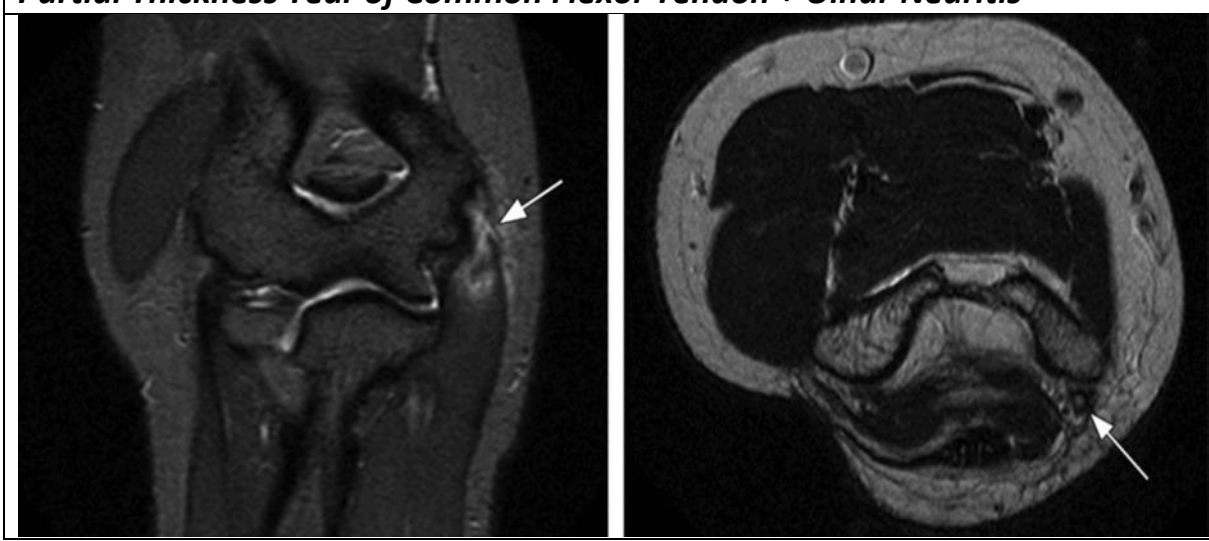
B. Medial Epicondilitis = Golfer's Elbow

- Degeneration of the common flexor tendon secondary to overload of the flexor muscle group that arises from the medial epicondyle.

Tendinosis



Partial Thickness Tear of Common Flexor Tendon + Ulnar Neuritis



❖Little League Elbow

- Baseball pitchers between 8 and 12 years of age experience
- MRI may show marrow edema and irregularity of the medial epicondylar apophysis.
- Skeletal scintigraphy demonstrates asymmetrical increased uptake in the symptomatic medial epicondyle

Mechanism of injury:

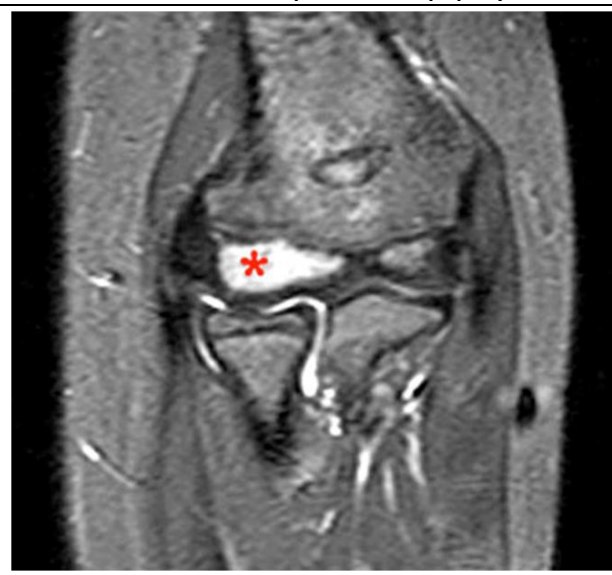
- The medial apophyseal plate is biomechanically weaker than the anterior band of the ulnar collateral ligament and is susceptible to injury when a valgus force generated during throwing overwhelms the growth plate.
- The flexor pronator group of muscles exerts traction on the weak physeal plate during the act of throwing.

❖Panner's disease

- An osteochondrosis of the humeral capitellum.
- Benign, self-limited condition
- Male athletes
- Age: between 7 and 12 years of age.
- Location: entire capitellar epiphysis is typically involved.
- Clinical picture: pain, swelling, and tenderness over lateral aspect of the elbow.

Imaging Findings:

- Rarefaction and flattening of the capitellar epiphysis.
- Fragmentation, fissuring, and sclerosis of the capitellum can also be observed.
- MR may show diffuse bone marrow edema within the capitellar epiphysis.

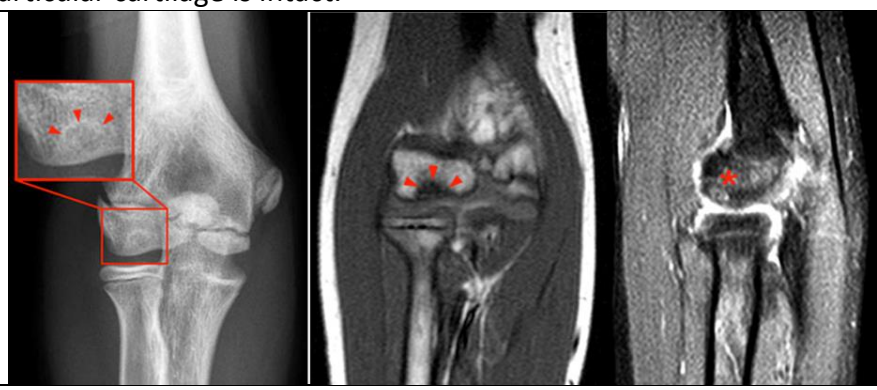


❖Osteochondritis Dissecans

- Location: ***anterior aspect of the capitellum***.
- Male athletes
- Age: between 12 and 15 years
- Combination of injury from repetitive trauma and a tenuous blood supply to the capitellum leads to osteochondritis dissecans.

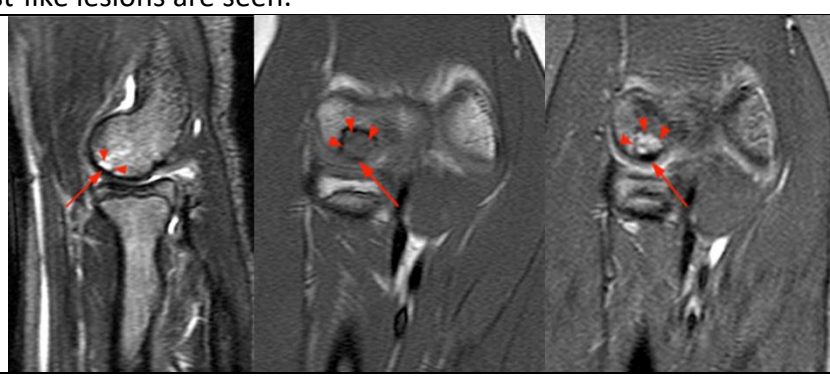
Stable Osteochondritis Dissecans:

- A region of marrow edema lies within the anterior capitellum (asterisks) with a thin low signal intensity margin on T1-weighted images (arrowheads).
- Overlying articular cartilage is intact.



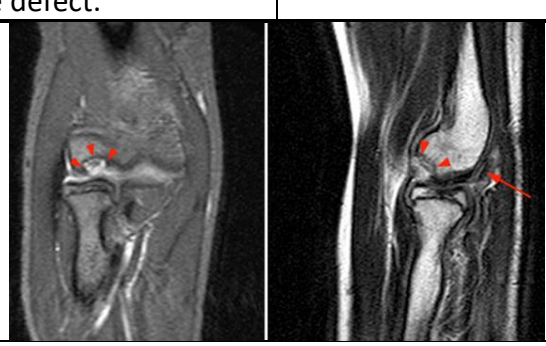
Unstable Insitu, Non-displaced Osteochondral Dissecans

- Curvilinear lesion within the anterior aspect of the capitellar epiphysis (arrows) is surrounded by high signal intensity on fluid sensitive images (arrowheads) and several small adjacent cyst-like lesions are seen.



Unstable Displaced Osteochondritis Dissecans

Osteochondral defect of the anterior aspect of the capitellum (arrowheads). The margins of both the articular cartilage and subchondral bone are disrupted with fluid-like signal within the defect.	The displaced osteochondral fragment (arrow) lies posterior to the capitellum on the sagittal image.



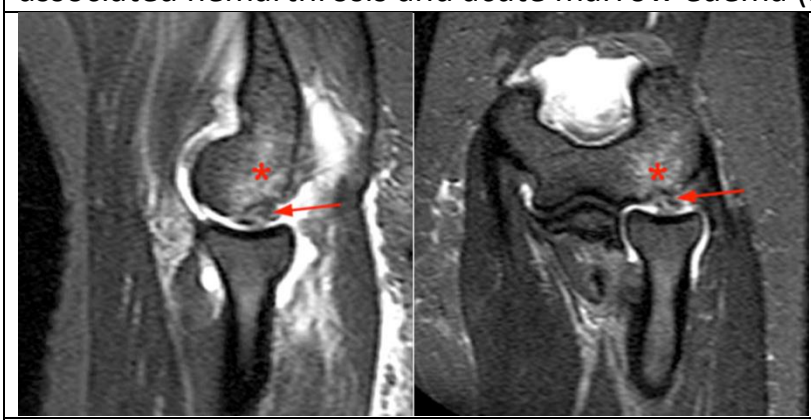
❖Osteochondral Fracture

- Shearing and impaction fractures of the capitellum can also occur,
- Less common than Panner's disease and osteochondritis dissecans.
- Location: ***posterior capitellum***.

Associations:

- Fractures or contusions of the anterior aspect of the radial head and coronoid process.
- Lateral ulnar collateral ligament

A displaced osteochondral fracture of the posterior capitellum (arrow) with associated hemarthrosis and acute marrow edema (asterisks).



Osteochondral fractures of the posterior capitellum and anterior aspect of the radial head

❖Biceps Tendon Tear

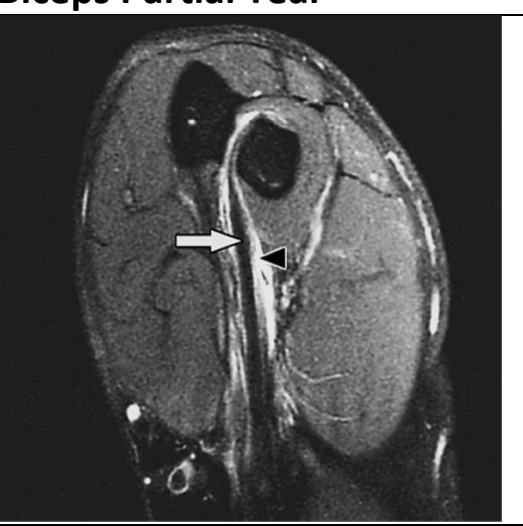
- The biceps tendon begins approximately 5 cm proximal to the elbow and inserts on the radial tuberosity.
- The tendon is flattened and approximately 10 cm in length and follows an oblique course as it travels from the superficial ulnar aspect above the elbow to the deep radial aspect below the elbow to insert on the radial tuberosity.

<u>FABS position:</u> flexed elbow, abducted shoulder, forearm supinated

Planned sections oriented perpendicular to the radial shaft.

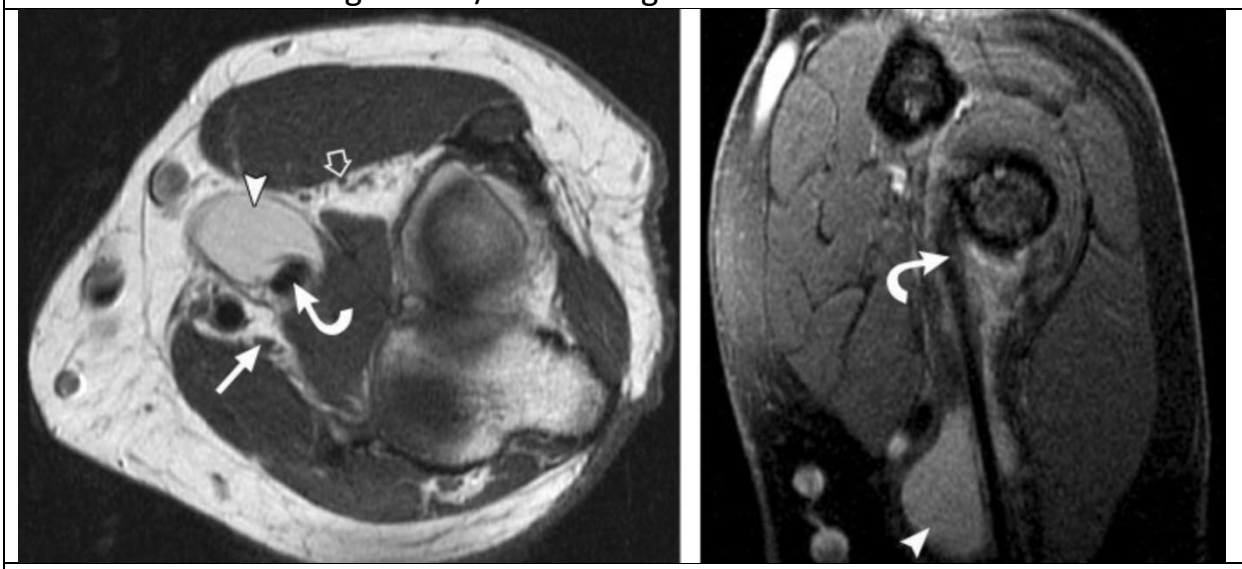
Normal Biceps Tendon

Biceps Partial Tear



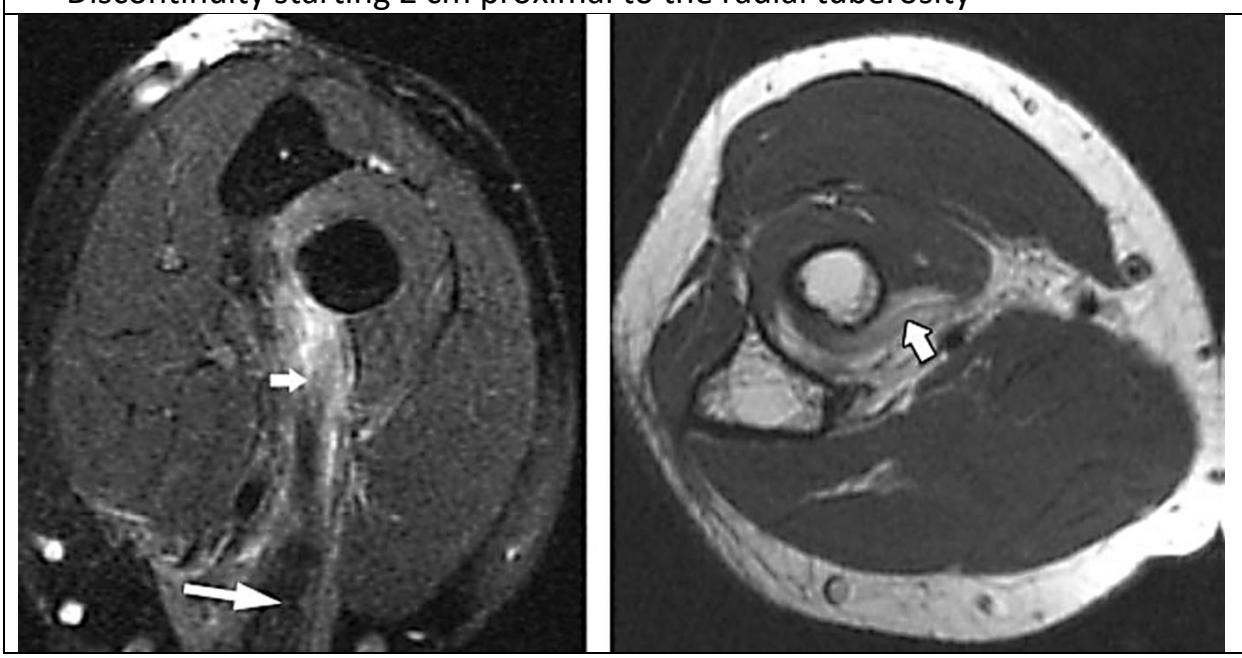
Partial Tear + Bursitis

Thickened abnormal appearing distal biceps tendon with retraction of some torn fibers and surrounding edema/hemorrhage



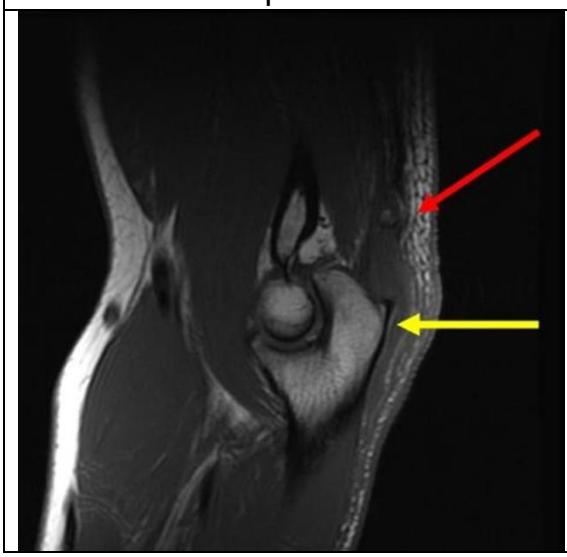
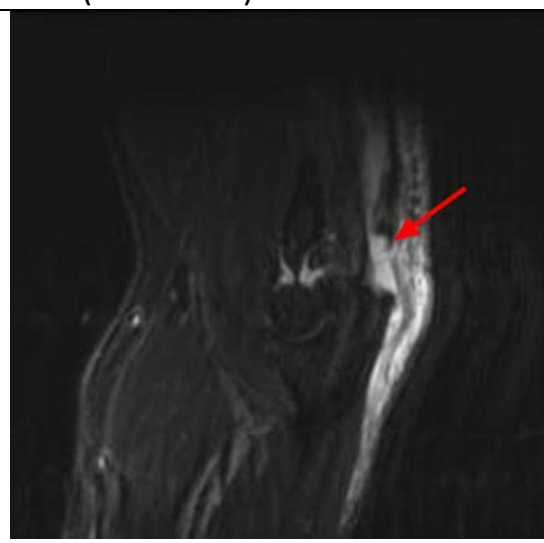
Complete Tear

- Non-visualization of the tendon close to its insertion site.
- Thickened proximal part of the tendon (long arrow in a)
- Discontinuity starting 2 cm proximal to the radial tuberosity



❖Triceps Tendon Avulsion

- Triceps tendon injuries are uncommon.
- Triceps tendon injuries are more common at the insertion onto the olecranon rather than at the myotendinous junction.

Sagittal T1	**Sagittal STIR**
Avulsion of triceps tendon from the olecranon (red arrow)	
	

Elbow Fractures in Children

Mechanism of Injury:

- Hyperextension
  - Injury to the elbow joint is the result of hyperextension or extreme valgus due to a fall on the outstretched arm.
- Extreme valgus
  - The normal elbow already has a valgus positioning. When a child falls on the outstrechted arm, this can lead to extreme valgus.

i. Fat Pad Sign and Joint effusion

Normally:

- On lateral view of the elbow flexed in 90: Anterior fat pad is seen on anterior aspect of the joint.
- Posterior fat pad is no seen since the posterior fat is located within the deep intercondylar fossa.

Positive fat pad sign:

- Distention of the joint will cause the anterior fat pad to become elevated and the posterior fat pad to become visible.
- Any elbow joint distention either hemorrhagic, inflammatory or traumatic.

ii. Radio-capitellar Line

Normally:

- A line drawn through the centre of the radial neck should pass throught the centre of the capitellum, whatever the positioning of the patient.

In dislocation of radius:

This line will not pass through the centre of the capitellum.

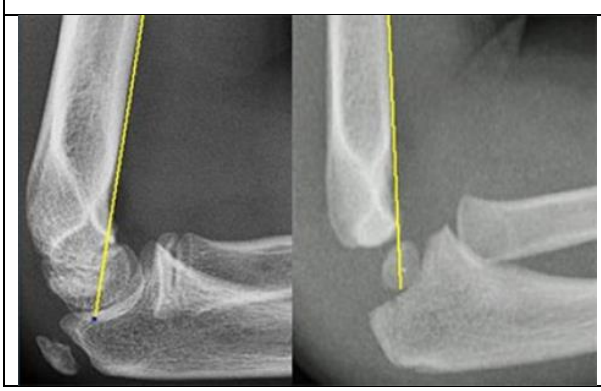
iii. Anterior Humeral Line.

Normally:

A line drawn on a lateral view along the anterior surface of the humerus should pass through the middle third of the capitellum

In supracondylar fracture:

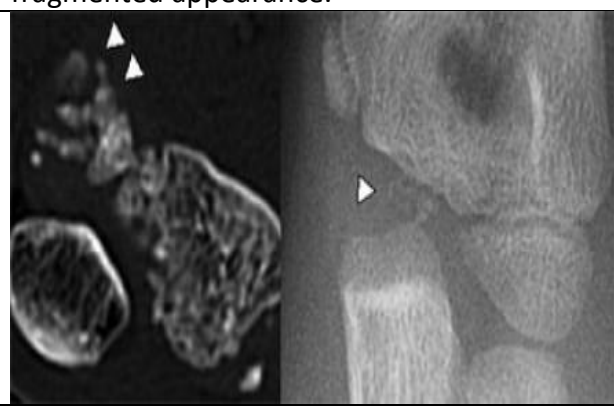
Anterior humeral line usually passes through the anterior third of the capitellum or in front of the capitellum due to posterior bending of the distal humeral fragment.



iv. Ossification Centres

- There are 6 ossification centres around the elbow joint.
- They appear and fuse to the adjacent bones at different ages.

- This order of appearance is specified in the mnemonic **C-R-I-T-O-E** (Capitellum - Radius - Internal or medial epicondyle - Trochlea - Olecranon - External or lateral epicondyle).
- The ages at which these ossification centres appear are highly variable: 1-3-5-7-9-11 years.

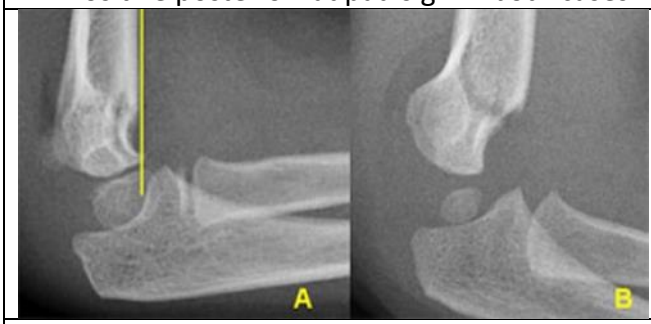
C-R-I-T-O-E	The Trochlea has two or more ossification centres which can give the trochlea a fragmented appearance.
	

Common Elbow fractures

- Supracondylar >60%
- Lateral condyle 10-20%
- Medial epicondyle 10%
- Radial neck
- Olecranon

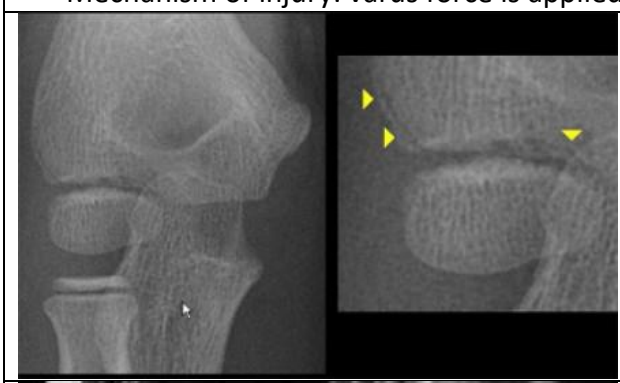
1) Supracondylar Fracture

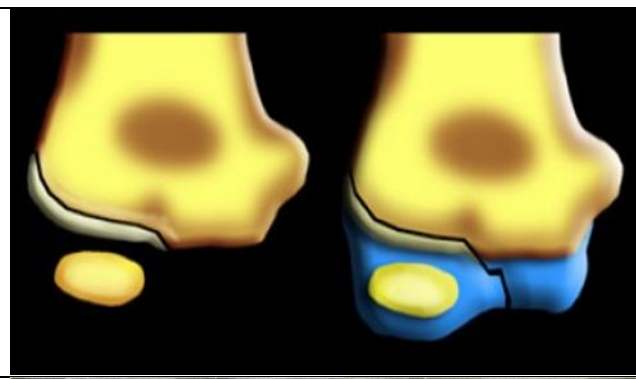
- > 60% of all elbow fractures in children
- > 95% of supracondylar fractures are hyperextension type due to fall on outstretched hand.
- Anterior humeral line passes through the anterior third of the capitellum.
- Positive posterior fat pad sign in both cases

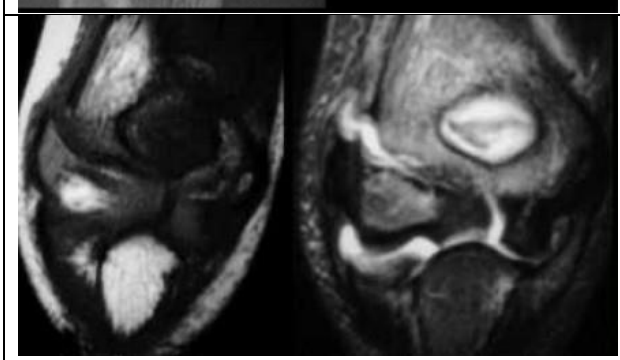


2) Lateral Condyle Fractures

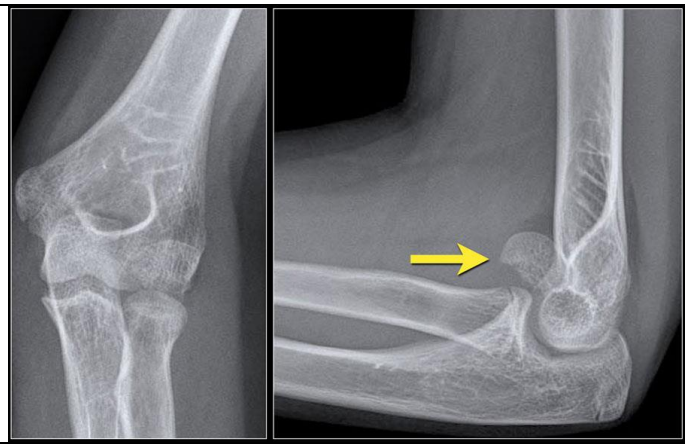
- 2nd most common distal humerus fracture in children.
- Ages of 4 and 10 years.
- Salter-Harris IV epiphysiolysis fractures.
- Mechanism of injury: varus force is applied to the extended elbow.







3) Capitellum Fracture



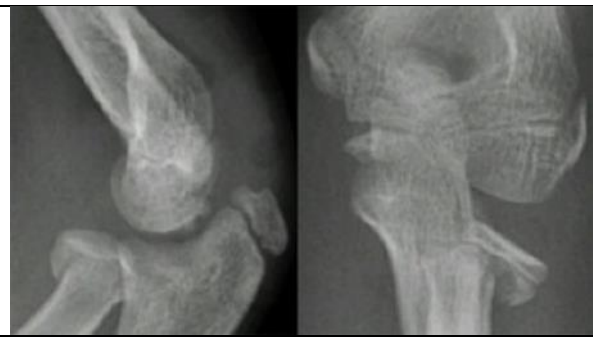
4) Medial Epicondyle Avulsion Fracture

- Mechanism of injury: Acute valgus stress due to a fall on the outstretched hand or sometimes due to armwrestling.
- Chronic injuries do occur in young athletes (little league elbow).
- 50% incidence of associated elbow dislocations
- The medial epicondyle is an extra-articular structure and avulsion will not produce joint effusion.
- When the trochlea is not yet ossified the avulsed fragment may simulate a trochlear ossification centre.

Normally: Located on the dorsal side of the elbow.	Avulsed medial epicondyle: are located more distally and anteriorly; Interposed between articular surface of humerus and olecranon

5) Radial Neck Fracture

- In adults fractures usually involve the articular surface of the radial head.
- In children radial neck fractures because metaphyseal bone is weak due to constant remodelling.
- Usually it is a Salter Harris II fracture.



6) Radial Head Dislocation

Radius Pulled Elbow (Nursemaid's elbow)

In children When the forearm is pulled the radial head moves distally and the ligament slips over the radial head and becomes trapped within the joint.

7) Olecranon Fractures

- Olecranon fractures in children are less common than in adults.
- Associated with radial neck fractures and radial dislocations.

Olecranon apophysis has undulating faintly sclerotic margins.
The growth plate has a different oblique course compared to a fracture-line.

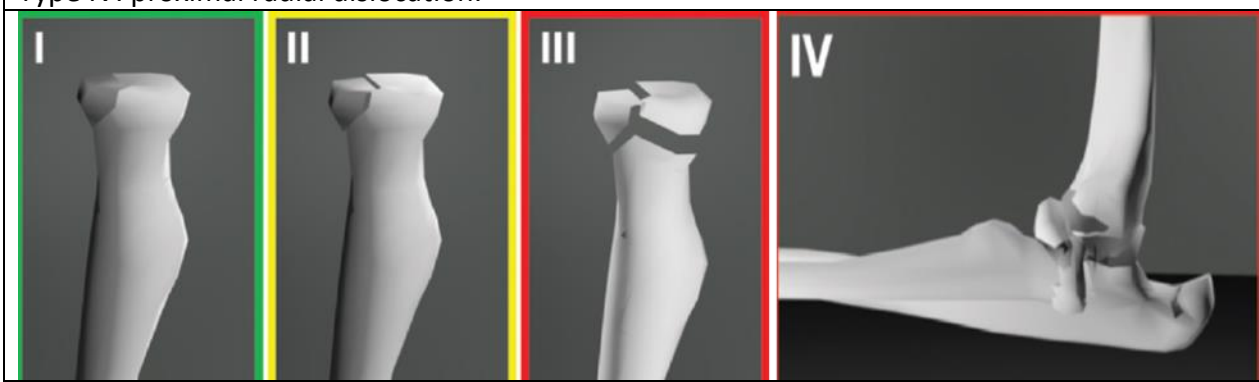
Traumatic Elbow Injuries

1) Radial Head and Neck Fractures

- most common elbow fractures in adults
- 50% of elbow fractures.

❖ Mason-Johnston classification system

Type I: no or only minimal (<2 mm) displacement.
Type II: displacement > 2 mm and articular surface involvement of less than 30%.
Type III: comminution of the radial head.
Type IV: proximal radial dislocation.



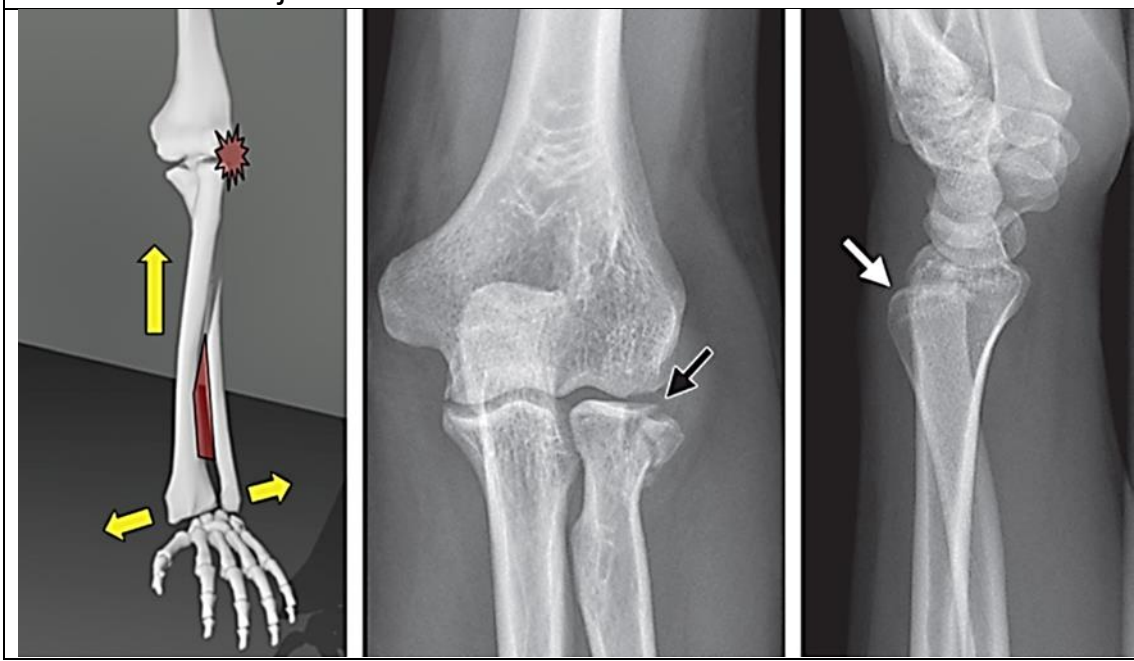
Nondisplaced radial neck fracture
Anterior and posterior fat pad elevation

Displaced radial head fracture (arrow) that involves < 30% of the articular surface

Chisel fracture

Essex-Lopresti fracture-dislocation

= Axial loading along the forearm => Comminuted radial head fracture +
Distal radioulnar joint dislocation



2) Distal Humerus Fracture

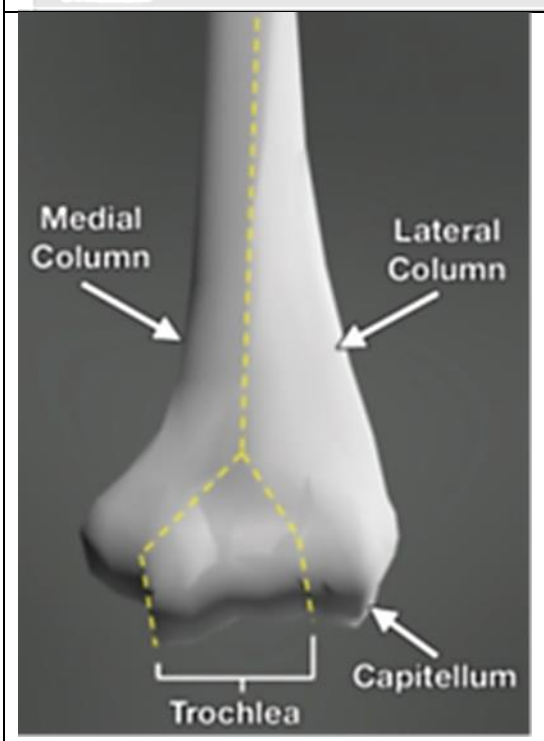
Two bone columns that provide primary load-bearing support to the arm:

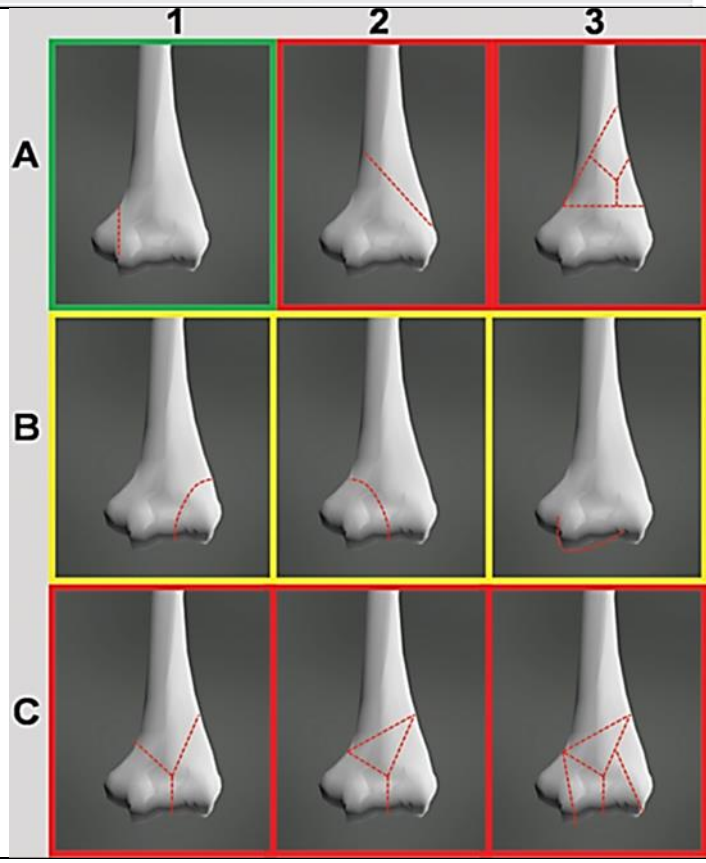
- The lateral column, which extends distally to the capitellum articulation.
- The medial column, which extends to the medial epicondyle.

AO-ASIF recommendations for morphologic classification of distal humerus fractures

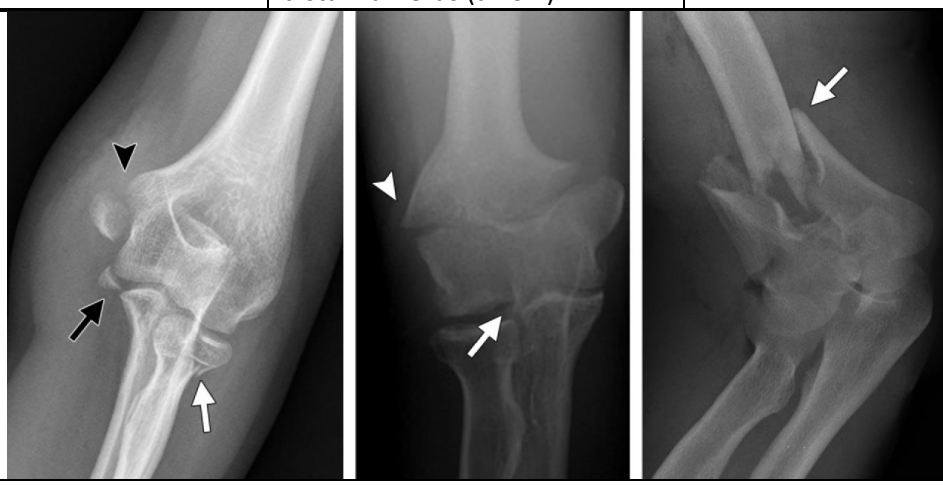
Simplified Classification System for Fractures of the Distal Humerus

	Subtype		
Main Type	1	2	3
A, extraarticular fractures	Apophyseal avulsion	Simple metaphyseal fracture	Metaphyseal fracture with comminution
B, partial articular fractures with or without column involvement	Lateral condylar fracture in the sagittal plane	Medial condylar fracture in the sagittal plane	Frontal articular fracture in the coronal plane
C, articular fractures with disruption of both columns	Both articular and metaphyseal simple fractures	Simple articular fracture with metaphyseal fracture comminution	Both articular and metaphyseal comminution



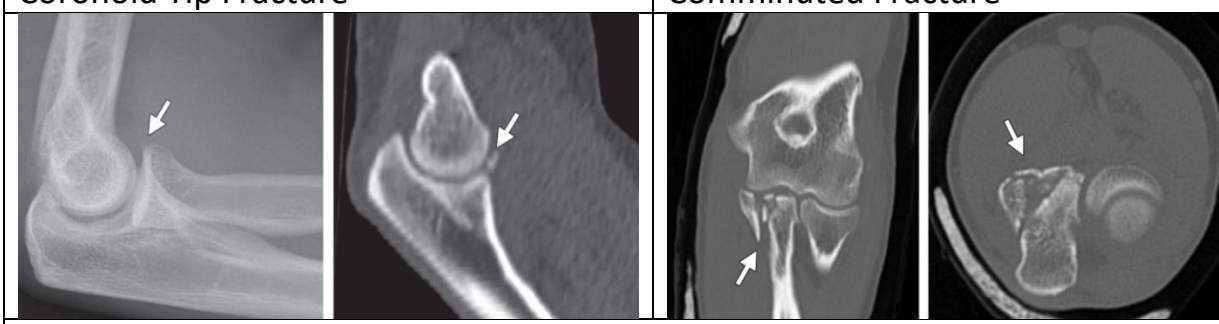


AO-ASIF type A1 fracture	AO-ASIF type C1	AO-ASIF type C3 fracture
Mildly displaced medial epicondylar fracture	Transverse metaphyseal fracture (arrowhead) and a minimally displaced intraarticular fracture of the distal humerus (arrow)	Comminuted intraarticular fracture of the distal humerus (arrow)



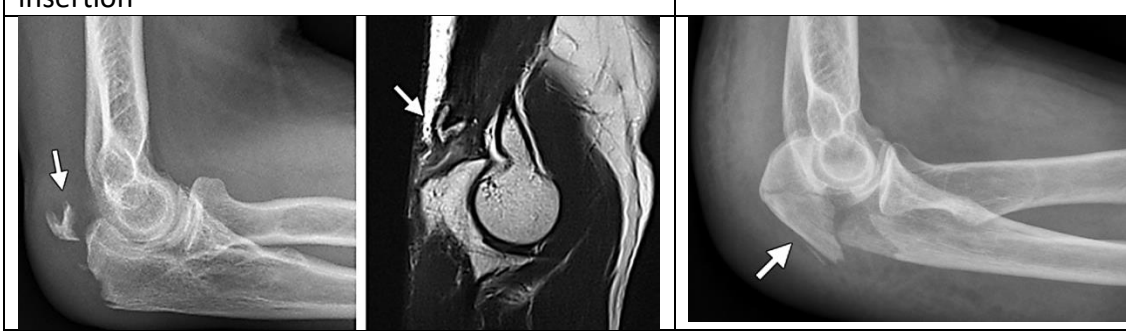
3) Coronoid Process Fracture

Coronoid Tip Fracture	Comminuted Fracture



4) Olecranon Process Fractures

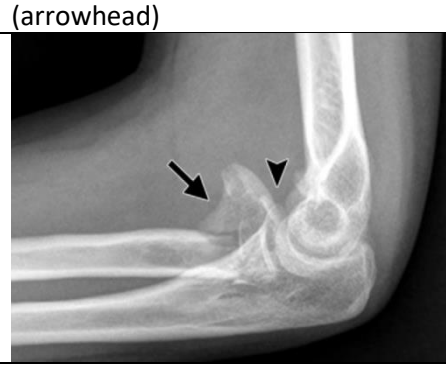
Avulsion Fracture at site of triceps tendon insertion	Comminuted Fracture



5) Galeazzi Fracture Dislocation	6) Monteggia Fracture Dislocation
Fracture of the proximal radius + Distal radioulnar joint dislocation.	Fracture of the proximal ulna + Anterior dislocation at the radial head

7) Elbow Dislocation

- 2nd most common type of joint dislocation in adults, after shoulder dislocation.
- Posterior dislocation is more common in adults.
- Anterior elbow dislocations is rare and are most often seen in children

Simple	**Complex** Posterior dislocations are often associated with radial head fractures	**Terrible Triad** Complex posterior dislocation. Comminuted radial head fracture (arrow) Coronoid process fracture fragment (arrowhead)
		

Congenital / Developmental Anomalies of Elbow joint

1) Congenital Radial Head Dislocation

- Commonest of the congenital anomalies of the elbow.
- An autosomal recessive familial condition.

- Bilateral in the majority of cases.
- Posterior dislocation (~70%) is more common
- Anterior dislocation (15%)
- Lateral dislocation (15%)

Diagnostic criteria have been proposed by McFarland:

- Absent or hypoplastic and flattened capitellum
- Prominent ulna epicondyle
- Partially abnormal trochlea
- Domed radial head articular surface with a long neck
- Negative ulnar variance

2) Proximal Radio-Ulnar Synostosis

- characterized by bony fusion at the proximal aspect of the radius and ulna
- Clinically: Inability to supinate the hand, leads to significant difficulty performing activities of daily living

Cleary and Omer Classification:

- Type I: Fibrous union; normally located radial head.
- Type II: osseous synostosis; normally located radial head.
- Type III: osseous synostosis; hypoplastic + posterior dislocated radial head.
- Type IV: short osseous synostosis; anteriorly dislocated mushroom shaped radial head.

3) Supracondylar Spur

- Supracondylar spur is typically located on the anteromedial humeral cortex
- 5 cm proximal to and pointing towards the medial epicondyle of the humerus.

Clinical presentation

- Most patients are asymptomatic

Complication:

- Median nerve compression + no pathology on imaging of the carpal tunnel.
- Brachial artery compression

Wrist

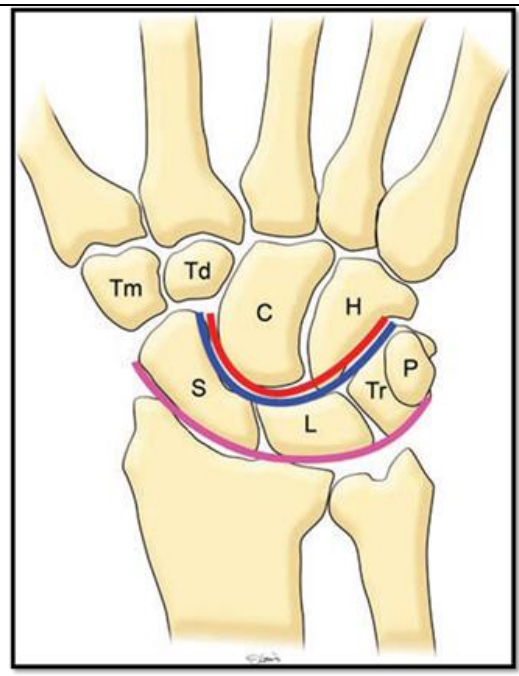
Normal Anatomy

Composed of 4 articulations:

- Radiocarpal joint
- Midcarpal joint
- Carpometacarpal joint
- Intercarpal joints

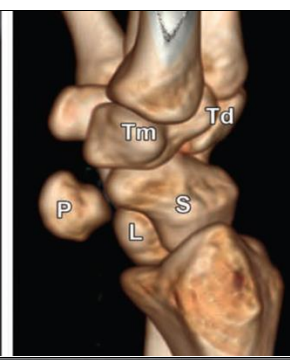
3Carpal Arcs (Gilula arcs):

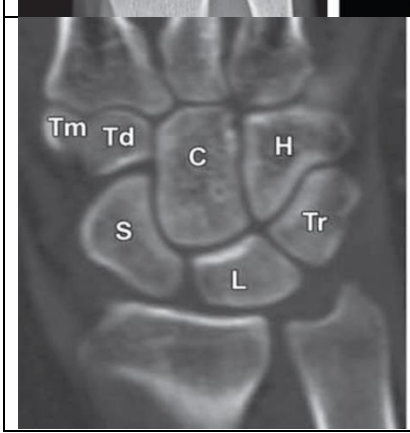
- Arc I (Pink) = proximal cortical margins of the proximal carpal row
- Arc II (Blue) = distal cortical margins of the proximal carpal row
- Arc III (Red) = proximal carpal surfaces of the hamate and capitate.

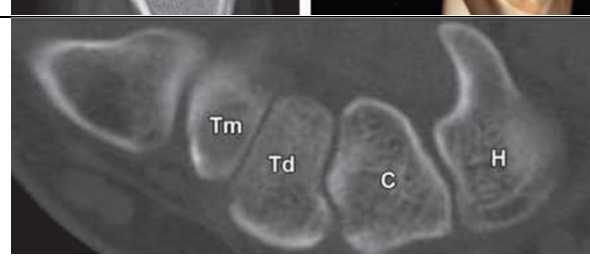


2 Rows and 8 Carpal bones :

Proximal row:	Distal row:
○ S = scaphoid	○ Tm = trapezium
○ L = lunate	○ Td = trapezoid
○ Tr = triquetrum	○ C = capitate
○ P = pisiform	○ H = hamate





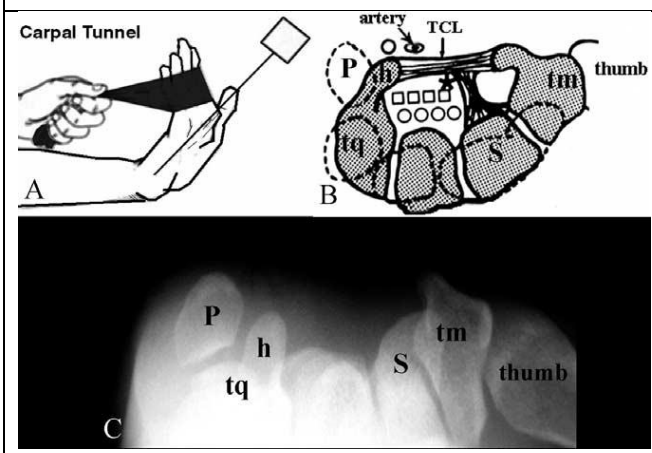


Standard views

PA	Lateral	Oblique

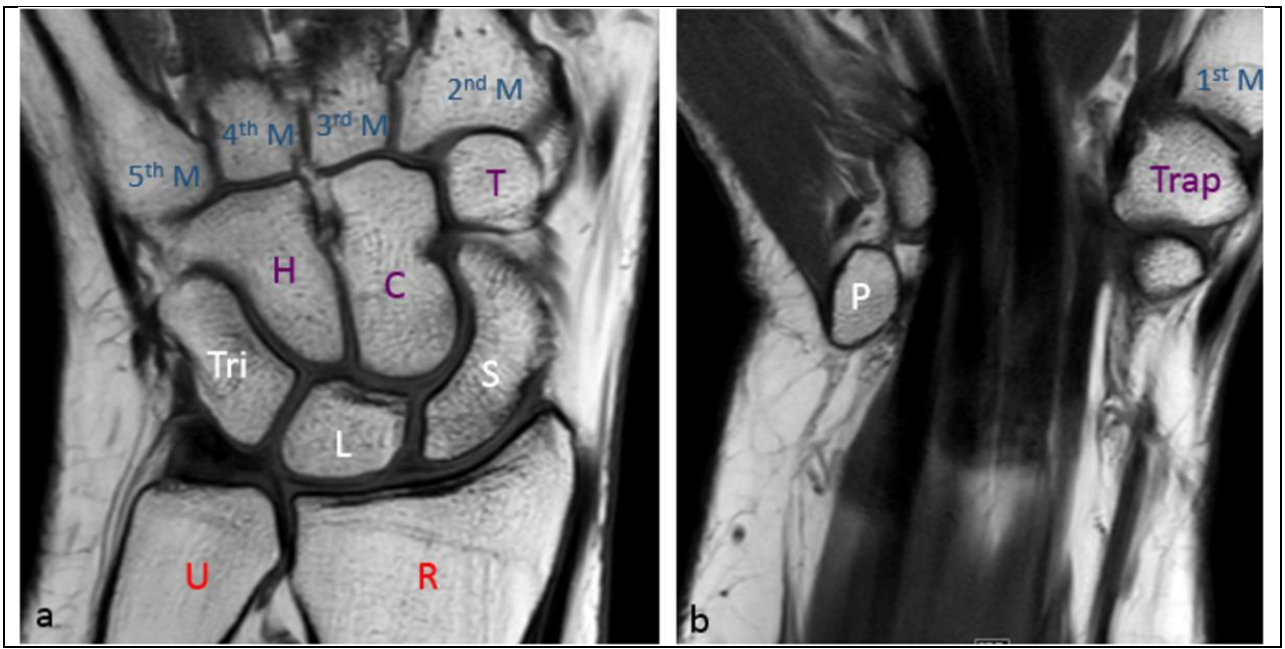
Radial deviation view	Ulnar deviation view	Lateral volar flexion	Lateral dorsiflexion

Carpal tunnel view	Scaphoid View = Semi-pronated oblique view



❖ MRI Protocol

- Positioning
  - Wrist neutral at side or overhead while prone.
- Technique
  - FOV 120 mm
  - No interslice gap (0mm Skip)
- Standard Sequences
  - Coronal gradient, PD, STIR
  - Sag PD : Help evaluate TFCC and intrinsic ligaments.
  - Axial PD FS



DD: Ulnar-Sided Wrist Pain

- Osseous injuries:
  - Ulnar styloid fracture - Pisiform fracture - Hamate hook Fracture
  - Keinbock's disease
  - Degenerative processes
  - Rheumatoid arthritis
- **Carpal fractures, dislocation and instability.**
- **Triangular fibrocartilage complex injury**
- **Ulnar impaction and impingement syndromes.**
- DRUJ instability
- Tenosynovitis
  - Extensor carpi ulnaris
  - Flexor carpi ulnaris
- Neurologic processes:
  - Guyon's canal Syndrome.
  - Neuroma of ulnar nerve

DD: Radial Side Wrist Pain

- Scaphoid factures – SNAC – SLAC
- Scopholunate dissociation.
- Radial styloid fracture.
- Trapezium fracture.
- ECRL – ECRB tendon avulsion.
- DeQuervain's disease.
- Basilar joint (CMC) Arthrosis of the thumb.

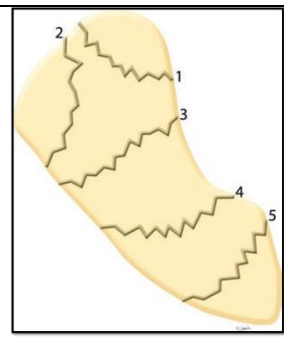
Carpal Fractures

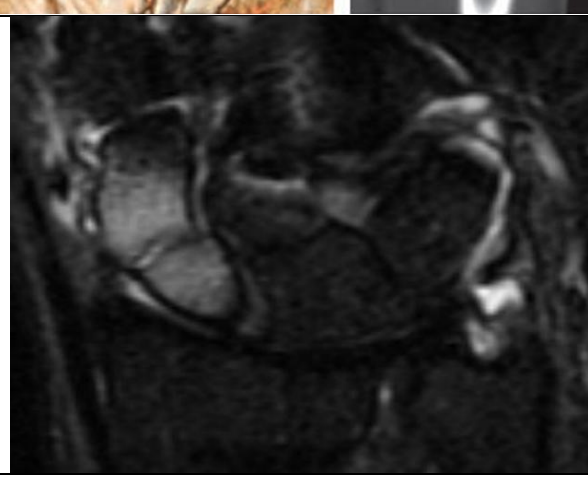
1) Scaphoid Fracture:

- Scaphoid fracture is the most common carpal fracture.
- Predominantly in active men
- Age: 2nd - 3rd decades
- Mechanism of injury: fall on an outstretched hand with forced dorsiflexion of the wrist.

Anatomic (Mayo Clinic) Classification:

1 = Distal articular surface
2 = Tuberosity
3 = Distal third
4 = Waist or middle third (most common type, 80%).
5 = Proximal pole.





❖ Scaphoid Fracture + Avascular Necrosis

- The scaphoid receives blood supply from branches of the radial artery
- 80% of its blood supply enters the scaphoid waist dorsally and supplies the proximal portion in a retrograde fashion.
- Avascular necrosis occurs in 13%–50% of scaphoid fractures

Coronal T1	Coronal T2	Coronal STIR

❖ Scaphoid Fracture + DISI

❖ Scaphoid Non-union Advanced Collapse (SNAC Wrist)

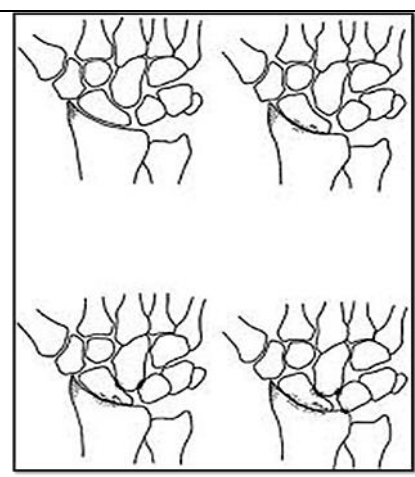
- Unstable or inadequately treated scaphoid fractures
  - ⇨ Scaphoid non-union and collapse
  - ⇨ Scaphoid non-union advanced collapse (SNAC wrist).
  - ⇨ Scaphoid sclerosis, cyst formation and flexion (humpback) deformity
  - ⇨ Dorsal intercalated segment instability (DISI) deformity
  - ⇨ "SNAC +" = long standing scaphoid non-union advanced collapse + radiocarpal degenerative osteoarthritis changes

❖ Scapholunate Advanced Collapse (SLAC)

- Undiagnosed or untreated chronic **scapholunate dissociation**
  - ⇨ Traumatic or atrumatic causes (most common cause of atrumatic cause is CPPD & RA)
  - ⇨ Specific pattern of osteoarthritis (associated with chronic scapholunate dissociation and chronic scaphoid non union)

❖ 4 Stages of Wrist Osteoarthritis (associated with SNAC & SLAC):

Stage 1: osteoarthritis between the distal scaphoid fragment and the radial styloid process
Stage 2: Radio-scaphoid arthritis
Stage 3: osteoarthrosis of the mid-carpal joint (Capitate-lunate & Scapho-capitate)
Stage 4: Pancarpal arthrosis



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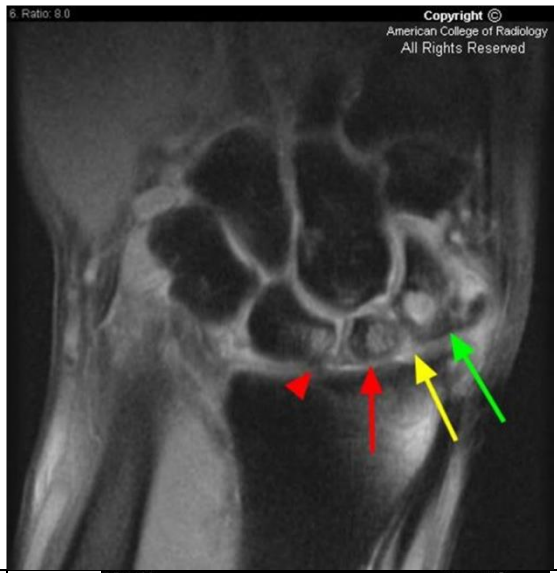
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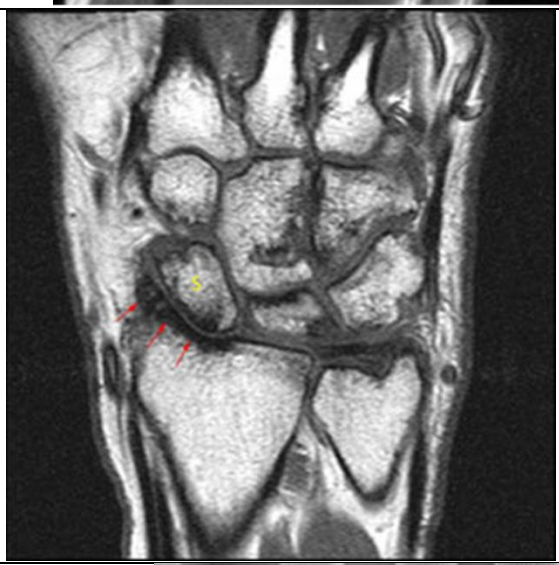

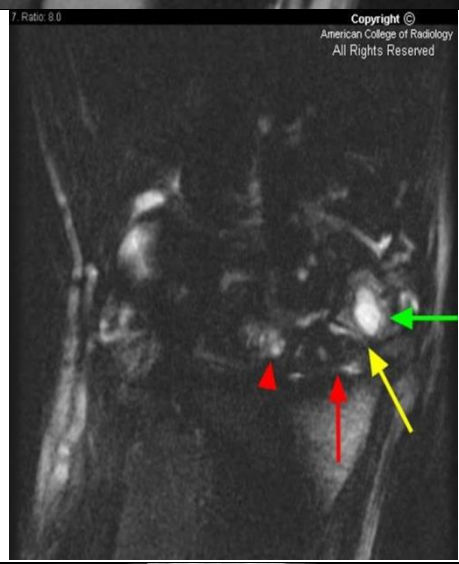
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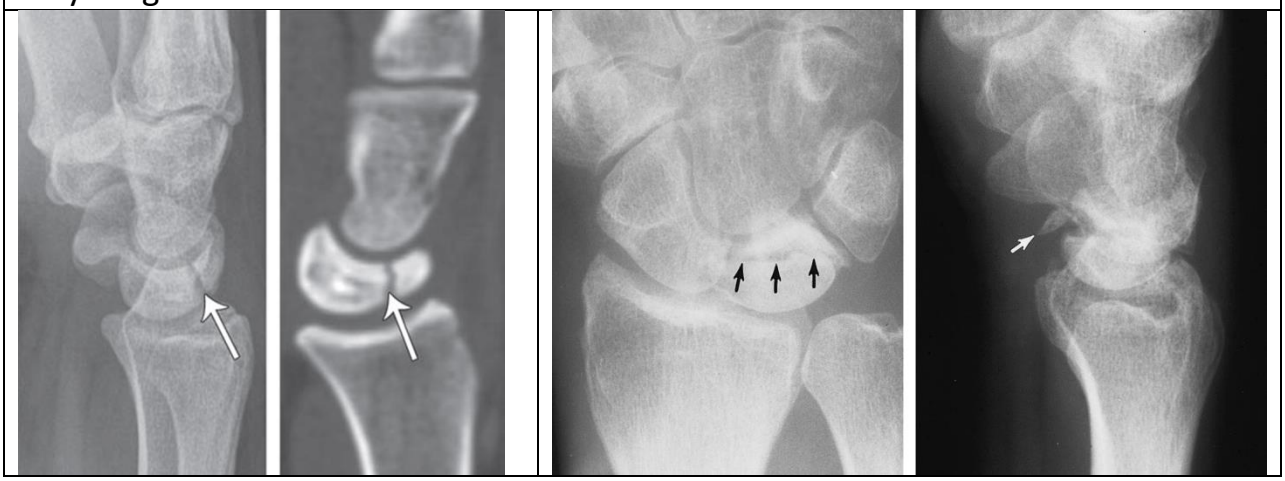
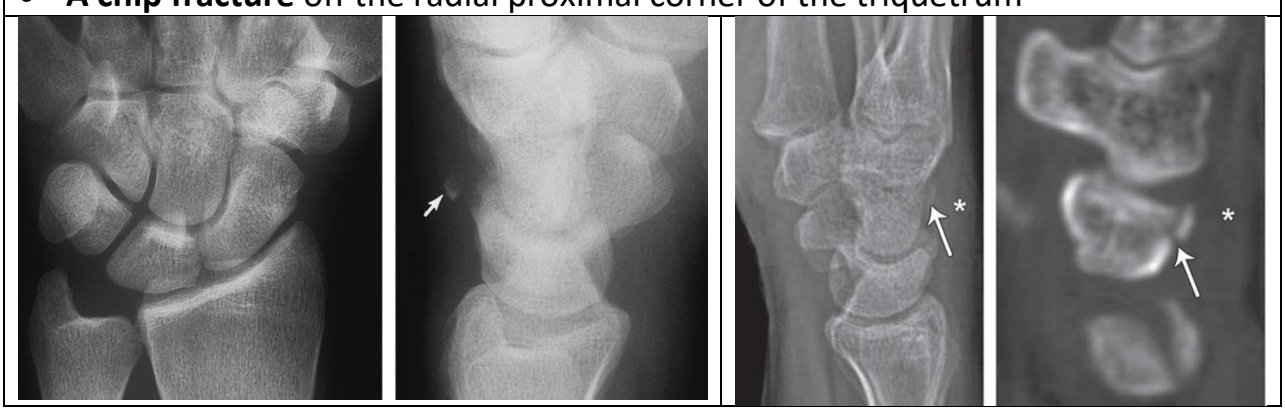
2) Lunate Fracture:

- Lunate fractures may result in carpal instability, nonunion, and avascular necrosis if left unrecognized.
- Kienböck disease is an avascular necrosis of the lunate, occurring primarily in young adults.



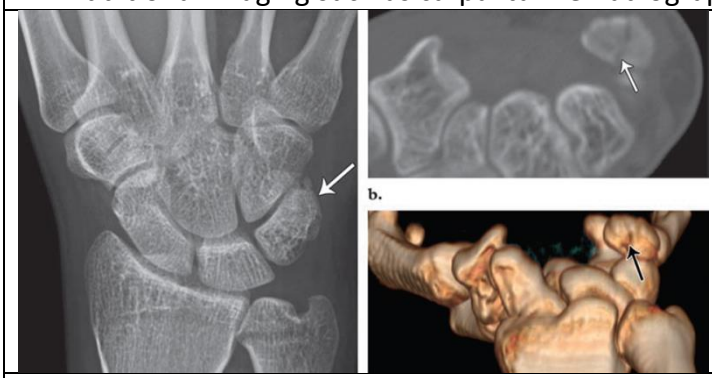
3) Triquetral Fracture:

- Triquetral fractures are 2nd most common carpal fractures.
- The majority of fractures are dorsal ridge fractures, which occur at the dorsal aspect of the triquetrum.
- They result from impingement of the ulnar styloid process against the dorsal surface of the triquetrum during wrist hyperextension and ulnar deviation.
- Dorsal ridge fractures are best visualized on lateral radiographs obtained with the wrist in slight pronation.
- **A chip fracture** off the radial proximal corner of the triquetrum



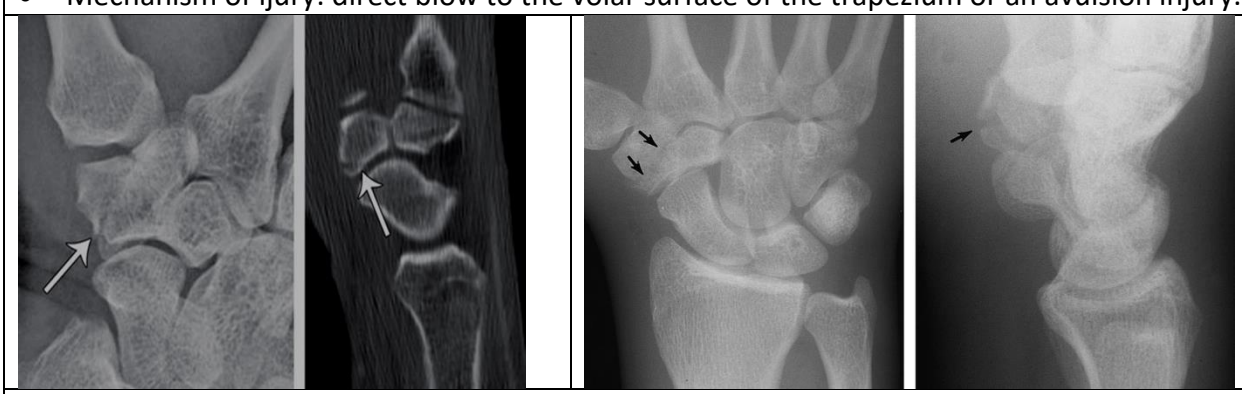
4) Pisiform Fracture:

- Pisiform fractures are uncommon.
- Mechanism of injury: fall on an outstretched hand, causing a direct blow to the pisiform.
- Owing to its close proximity to the ulnar nerve, fractures may cause ulnar nerve injury.
- Additional imaging such as carpal tunnel radiography or CT helpful to detect fracture



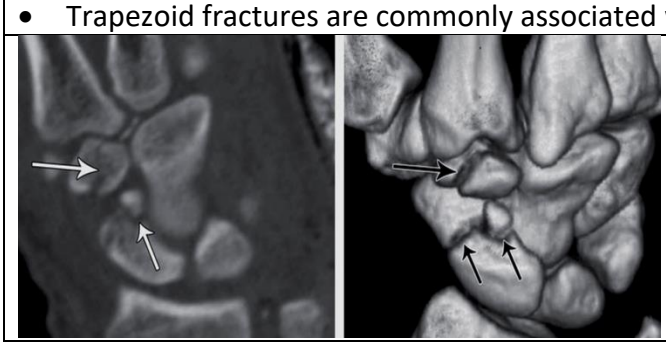
5) Trapezium Fracture:

- Fractures of the trapezium most commonly occur at the **trapezial ridge**.
- The trapezial ridge is a vertical prominence on the volar aspect of the trapezium, where ligaments and the flexor retinaculum insert.
- Mechanism of ijury: direct blow to the volar surface of the trapezium or an avulsion injury.



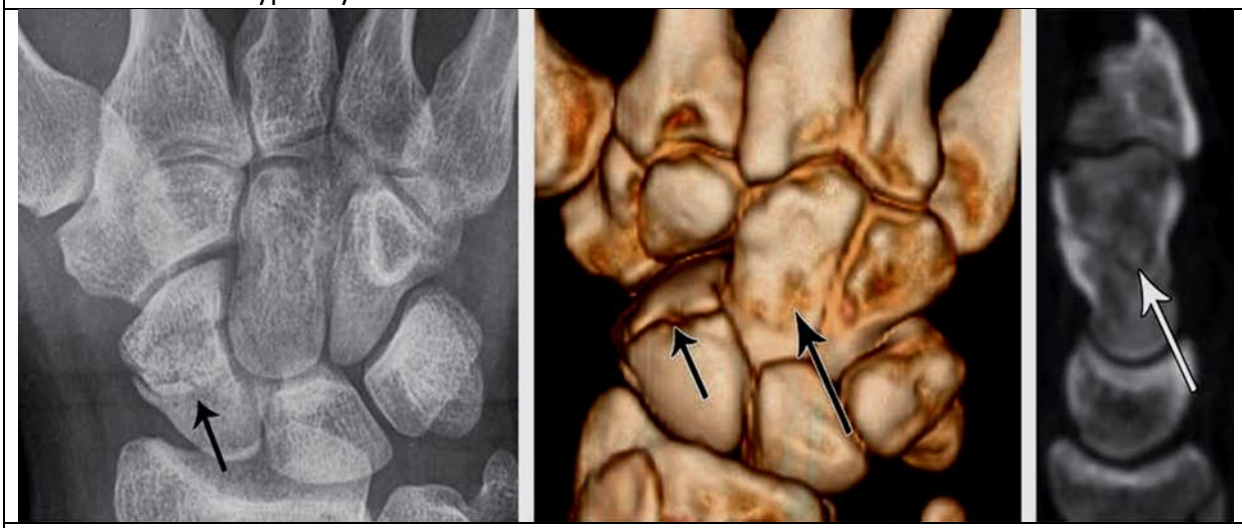
6) Trapezoid Fracture:

- The trapezoid is the least commonly fractured carpal bone.
- The mechanism is usually a high-energy axial blow to the second metacarpal.
- Trapezoid fractures are commonly associated with other carpal fractures



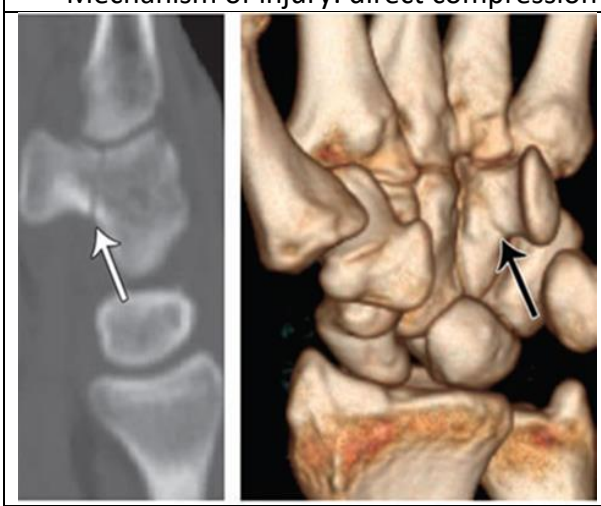
7) Capitate Fracture:

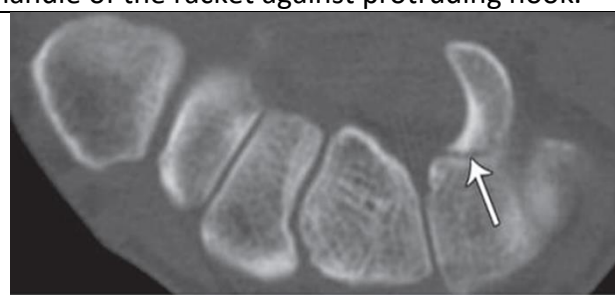
- The capitate is the largest of all the carpal bones, supported by strong palmar ligaments.
- Injuries to this bone are usually due to a high-energy hyperextension force.
- Fractures are typically transverse in orientation



8) Hamate Fracture:

- The hamate hook is the most frequent site of hamate fractures.
- They are most frequently encountered in **athletes participating in racket sports**.
- Mechanism of injury: direct compression of handle of the racket against protruding hook.





Carpal Coalition

- Fusion of two or more carpal bones.
- Can either be
  - Osseous (synostosis)
  - Cartilaginous (synchondrosis)
  - Fibrous (syndesmosis).

- Non-syndromatic congenital carpal coalition.
- Acquired intercarpal fusion :
  - Inflammatory arthropathy (e.g. rheumatoid arthritis, psoriatic arthritis, reactive arthritis)
  - Surgical arthrodesis.

Types are:

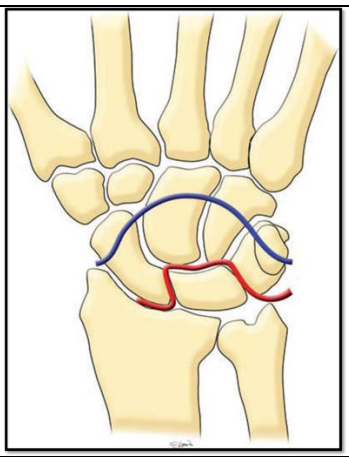
- **Luno-triquetral coalition**: much more common than all other types

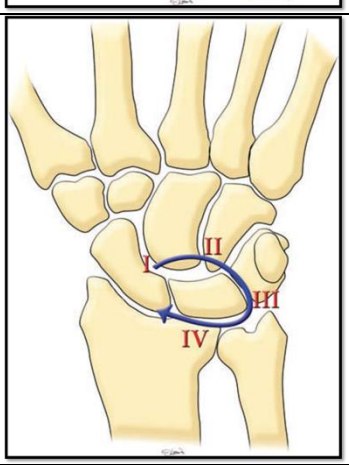
Carpal Dislocation and

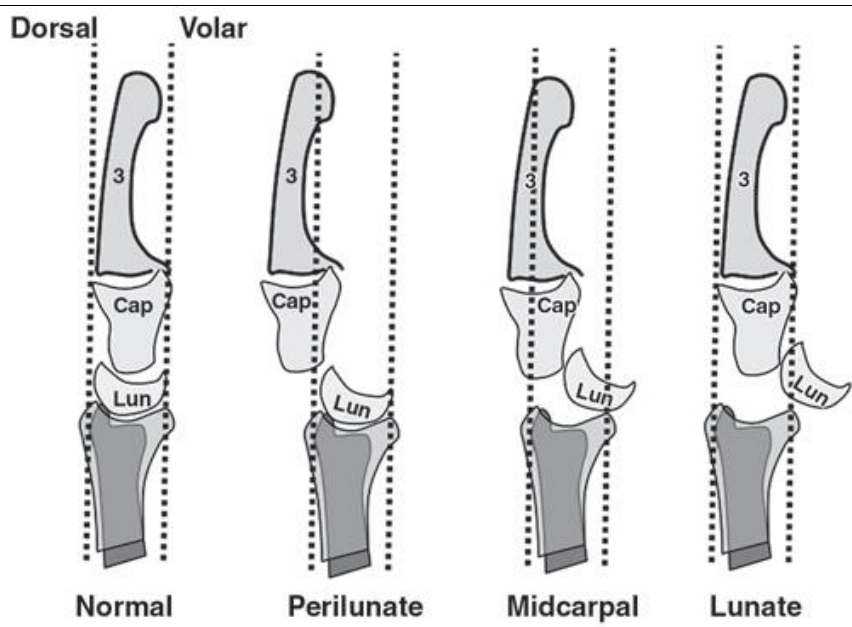
Fracture- Dislocation

❖ 2 Patterns of Injuries

- Dislocation without fracture: Pure ligamentous injuries around the lunate (red line) is called lesser arc injury (I–IV):
  - Scapholunate ligament
  - Lunocapitate ligament
  - Lunotriquetral ligament
  - Dorsal radiocarpal ligament
- Dislocation with associated fracture of one or more carpal bone (blue line) are called greater arc injury:
  - Scaphoid, trapezium, capitate, hamate, or triquetrum.
  - The fracture is mentioned first and is indicated by the prefix“trans-.”
  - The dislocation is mentioned second.





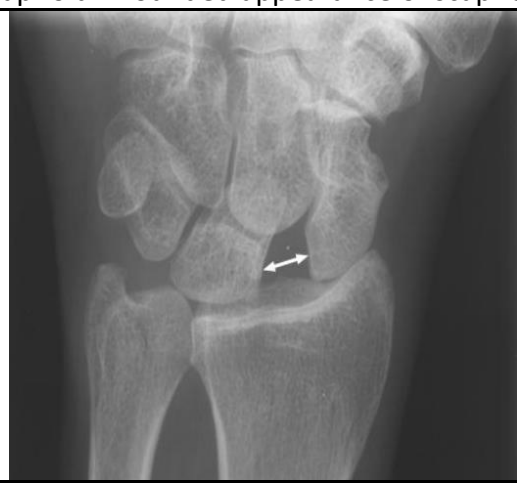


A) Scapholunate Dissociation

- Disruption of scapholunate joint
- Injury of scapholunate ligament

AP view:

- > 3 mm gap between the lunate and scaphoid (Terry-Thomas sign or David Letterman sign).
- A ring sign secondary to rotary subluxation of scaphoid = rounded appearance of scaphoid



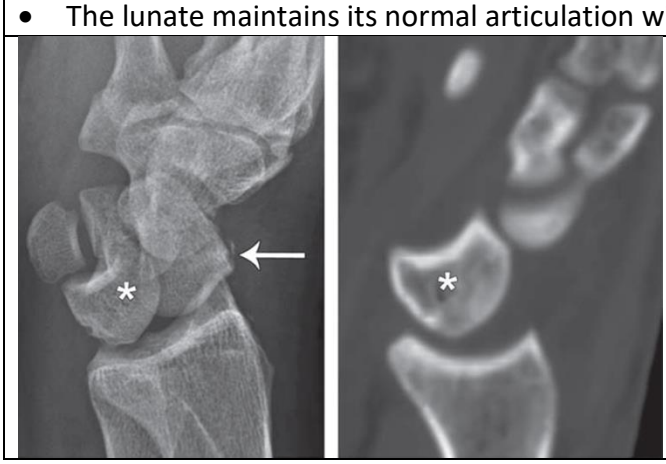
B)Perilunate Dislocation

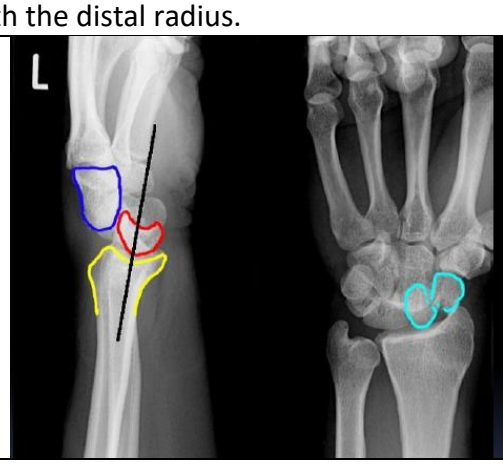
- 2-3 times more common than lunate dislocation.
- Disruption of the capitolunate joint
- 75% are accompanied by **scaphoid fracture => Trans-scaphoid perilunate dislocation**.
- Triquetrum, capitate and ulnar styloid fractures can also be seen.

- Perilunate dislocation without fracture: Pure ligamentous injuries around the lunate (red line) is called lesser arc injury.
- Perilunate dislocation with associated fracture of one or more bone (scaphoid, trapezium, capitate, hamate, or triquetrum) (blue line) are called greater arc injuries.

Lateral view:

- Posterior dislocation of the capitate relative to the lunate.
- The lunate maintains its normal articulation with the distal radius.



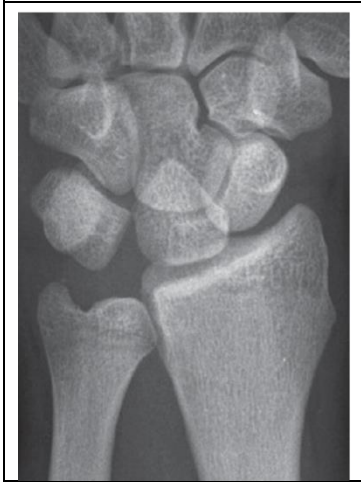


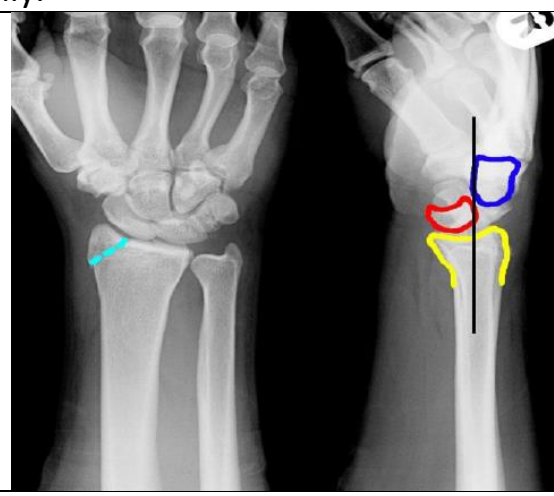
C) Midcarpal Dislocation

- due to rupture of the lunate - triquetral ligaments.

Lateral X-ray:

- The lunate dislocates volarly.
- The capitate and carpus dislocate dorsally.



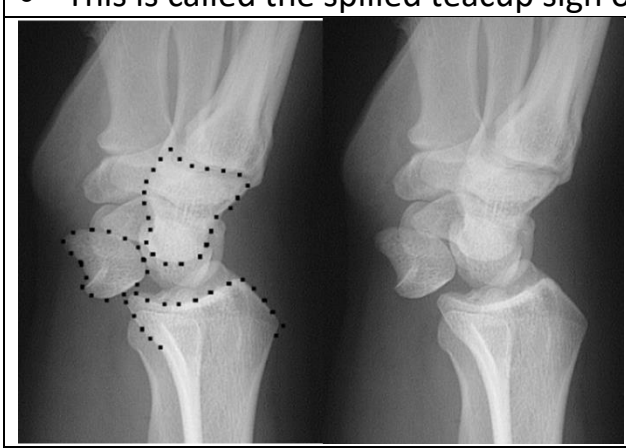
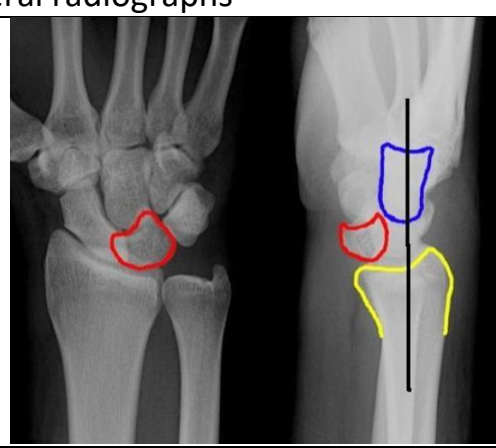


D) Lunate Dislocation

- Injury of the dorsal radiocarpal ligament

Lateral view:

- Lunate dislocates and rotates volarly out of the distal radial articulation
- The rest of the carpus assumes alignment with the radius
- This is called the spilled teacup sign on lateral radiographs

Kienböck Disease

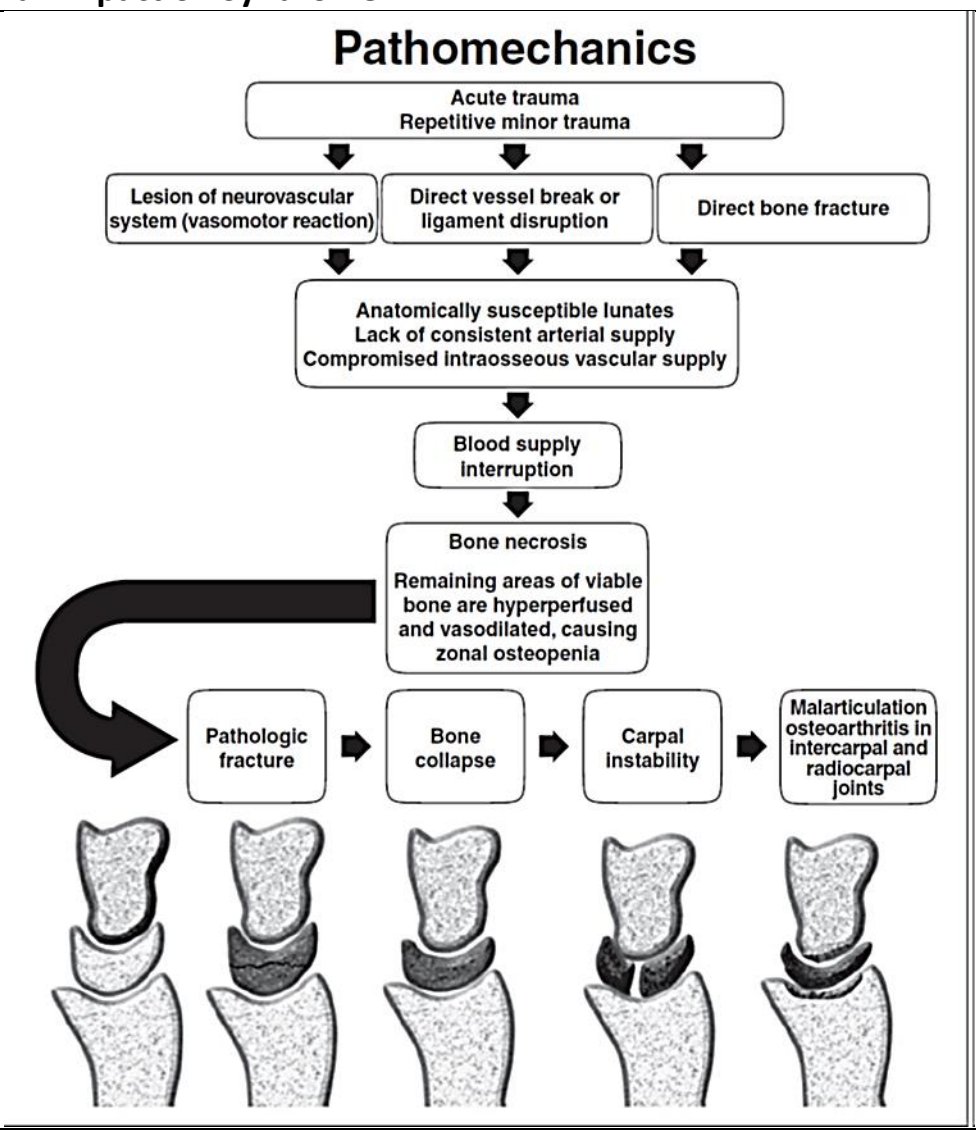
- Osteonecrosis involving the lunate
- Young adult men
- The association of negative ulnar variance and avascular necrosis of lunate is well known

MRI Findings:

- Sclerosis (low T1 and T2)
- Bone oedema (high T2, intermediate T1) may be seen in the acute phase, particularly on the radial side.

DD:

- ✓ **Ulnar Impaction Syndrome**

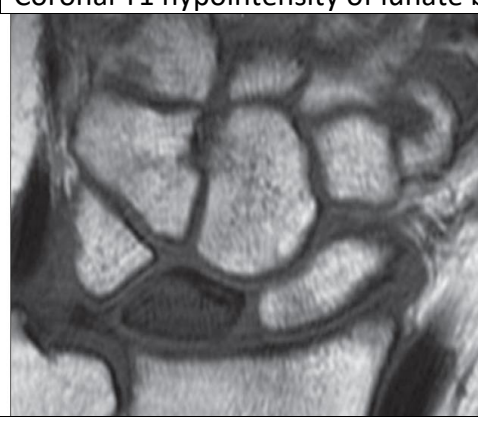


Lichtman Staging of Kienböck Disease

Stage	Radiographic and CT Findings	MRI Findings
I	Normal morphologic findings	Morphologic preservation
		Edema pattern in bone marrow
II	Normal morphologic findings	Morphologic preservation
	Sclerosis in bone marrow	Signal intensity low on T1-weighted images, variable on T2-weighted images
IIIA	Collapse of lunate bone	Morphologic collapse of lunate bone
	Radioscaphoid angle < 60°	Signal intensity low on T1-weighted images, variable on T2-weighted images
IIIB	Collapse of lunate bone	Morphologic collapse of lunate bone
	Radioscaphoid angle > 60°	Signal intensity low on T1-weighted images, variable on T2-weighted images
IIIC	Collapse of lunate bone	Morphologic collapse of lunate bone
	Coronal lunate fracture (chronic)	Signal intensity low on T1-weighted images, variable on T2-weighted images
		Coronal lunate fracture (chronic)
IV	Radiocarpal or midcarpal degenerative arthritis	Radiocarpal or midcarpal degenerative arthritis
		Signal intensity low on T1-weighted images, variable on T2-weighted images

Stage I Kienböck disease

Radiograph shows normal lunate bone.	Coronal T1 hypointensity of lunate bone.



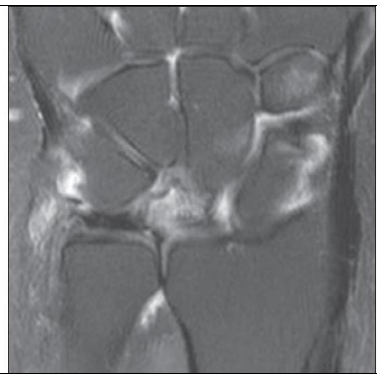
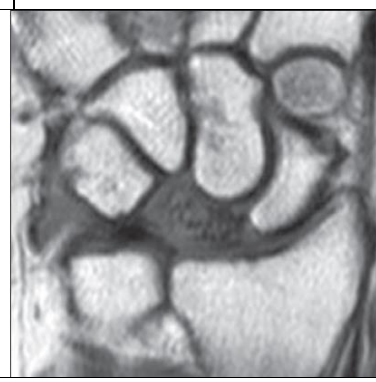
Stage II Kienböck disease

Radiograph shows increase in bone density of lunate compared with other carpal bones.	Coronal T1 shows decreased signal intensity on radial side of lunate bone.	Coronal T2-FS shows mild increase on signal intensity in lunate bone.

Size, shape, and anatomic relations of lunate are preserved.

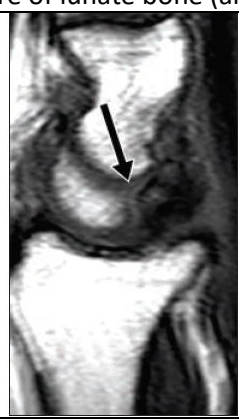
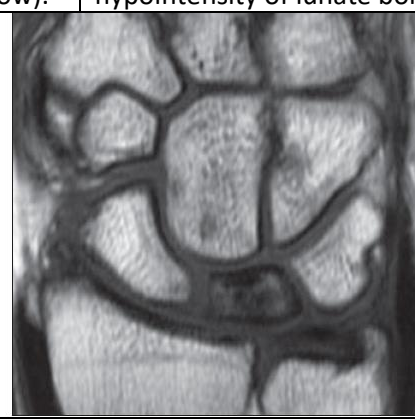
Stage III Kienböck disease

Radiograph shows lunate collapse and sclerosis	Coronal T2-FS shows diffuse hyperintensity and collapse of lunate bone.	Coronal T1 shows diffuse hypointensity of lunate bone.

Stage IIIC Kienböck disease + Negative ulnar variance is evident.

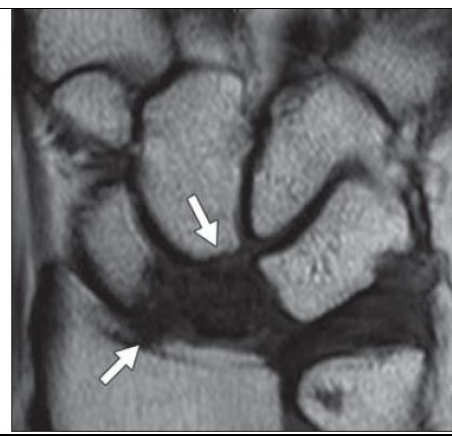
Radiograph shows mild lunate sclerosis and collapse.	Sagittal T1 shows coronal fracture of lunate bone (arrow).	Coronal T1 shows patchy hypointensity of lunate bone.

Stage IV Kienböck disease.

Radiograph shows collapse.	Sagittal T1 shows coronal fracture of lunate bone and elongation (arrow).	Coronal T1 shows marked hypointensity of lunate bone and collapse

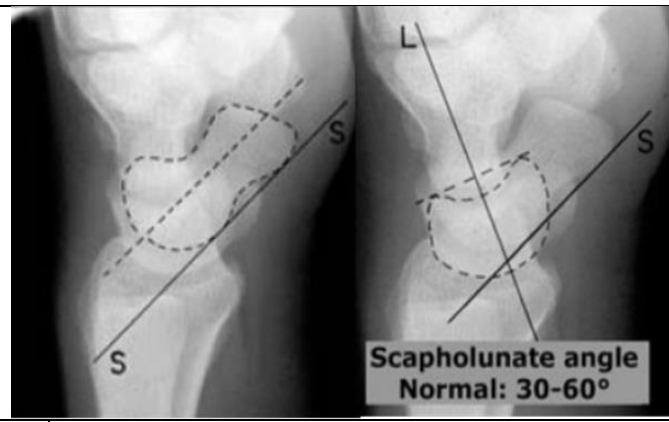
Osteoarthritic changes in radiolunate and midcarpal joints



Carpal Instability

Scapholunate Angle:

- **Normal range = 30°–60°**
- **VISI (Volar Intercalated Segmental Instability) <30°**
- **DISI (Dorsal Intercalated Segmental Instability) >60°**



DISI	VISI
Dorsal tilt of the lunate **Scapholunate angle is usually > 60º.** **Capitolunate angle is > 30º.**	**Volar rotation of the lunate** **Dorsal rotation of capitate and hamate.** **Scapholunate angle < 30°** **Capitolunate angle > 30°**

Wrist Impaction &

Impingement Syndromes

5 Types:

1) **Ulnar impaction syndrome: positive ulnar variance**
2) **Ulnar impingement syndrome: acquired short ulnar**

3) **Ulnar styloid impaction syndrome: long ulnar styloid**
4) **Ulnar Styloid Nonunion Impaction Syndrome**

5) **Hamatolunate impingement syndrome : type II lunate morphology (presence of an articulation between lunate and hamate)**

1) Ulnar Impaction Syndrome

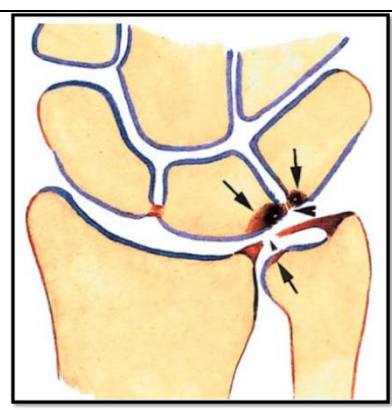
- Impaction of distal ulna upon the ulnar-sided carpal bones, particularly lunate
- Injury to the triangular fibrocartilage complex (TFCC).
- Middle-aged patients.

Predisposing factor ◦

- Positive ulnar variance
- Previous distal radial fracture with shortening or dorsal tilt
- Distal radial resection
- Madelung deformity

Imaging Findings:

- Positive ulnar variance
- Chondromalacia and bone marrow changes of ulnar head, ulnar side of lunate, and radial side of triquetral:
    - Bone edema (high T2, low-intermediate T1)
    - Subchondral sclerosis (low T1 and T2)
    - Subchondral cysts (round T2 hyperintensities)
- Central perforation of TFC
- Lunotriquetral ligament tear



2) Ulnar Impingement Syndrome

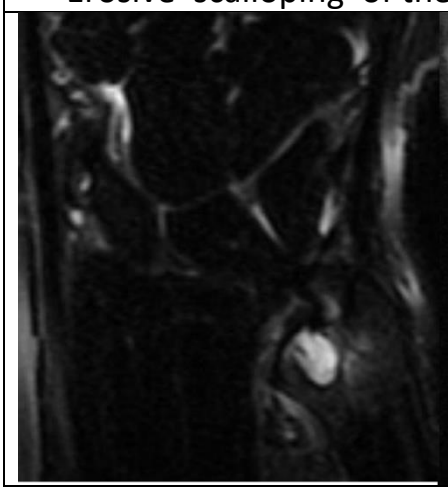
- A wrist condition caused by a shortened distal ulna impinging on the distal radius proximal to the sigmoid notch.

Predisposing Factors:

- Surgical resection of the distal ulna as part of management of wrist trauma,
- Rheumatoid arthritis
- Madelung deformity.
- Negative ulnar variance.

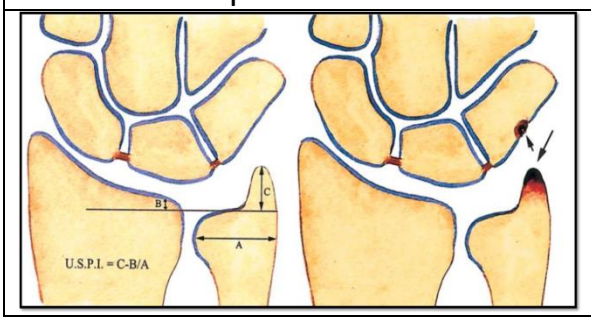
Imaging Findings:

- Ulnar shortening (usually surgical)
- Radioulnar convergence
- Subchondral sclerosis / local bone oedema where distal ulnar impinges radius
- Erosive 'scalloping' of the distal radius by the ulnar in later disease



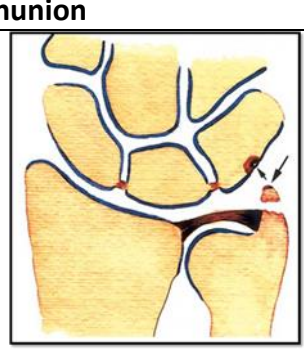
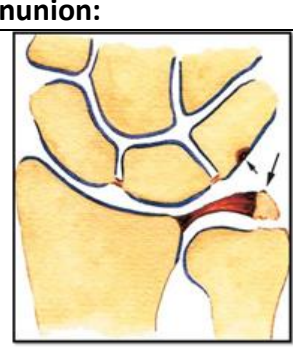
3) Ulnar Styloid Impaction Syndrome

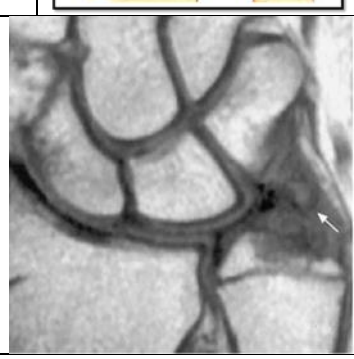
- A long ulnar styloid process impacting upon the triquetral bone.
- TFCC is usually intact.
- Unlar styloid > 6 mm in length
- Chondromalacia and bone marrow changes of the opposing articular surfaces: proximal pole of the triquetral bone and ulnar styloid tip.
- Chronic impaction can lead to lunotriquetral instability.

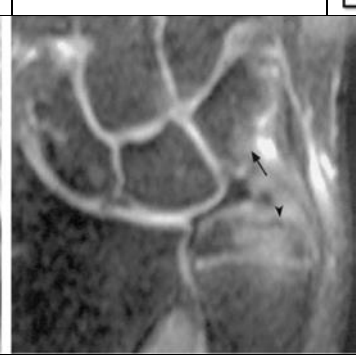


4) Ulnar Styloid Nonunion Impaction Syndrome

- The nonunited fragment acts as an irritative loose body, causing focal chondromalacia of the triquetral bone and subcortical sclerosis on the tip of the fragment

Type 1 ulnar styloid nonunion		**Type 2 ulnar styloid nonunion:**	
TFCC intact Distal radioulnar joint stable		Avulsion of the ulnar attachment of TFCC (palmer class IB lesion) Distal radioulnar joint unstable	



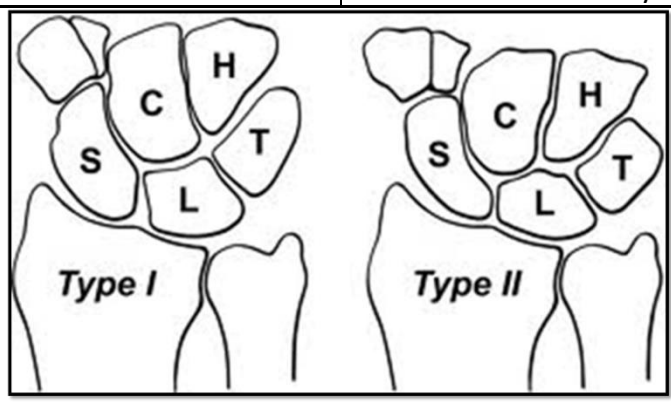


5) Hamatolunate Impingement

- An uncommon cause of ulnar-sided wrist pain.
- Type II lunate morphology (existence of a medial facet on the distal lunate for articulation with the hamate).

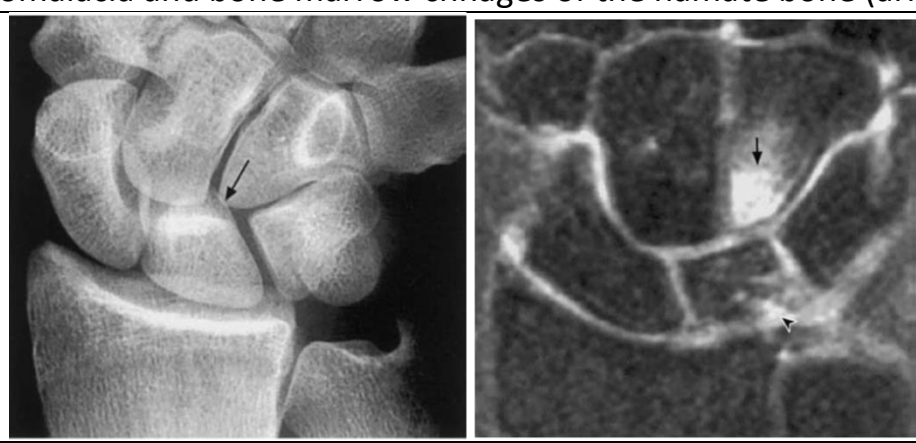
Lunate Morphology

Type I: lunates have a single distal articular facet for the capitate	Type II: lunates have an additional distal articular facet medially for the hamate



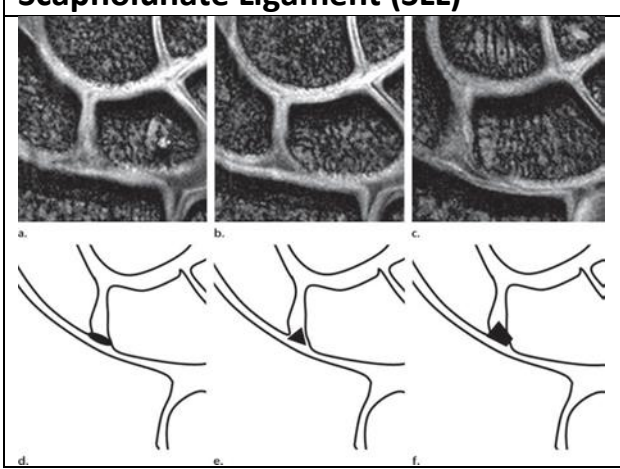
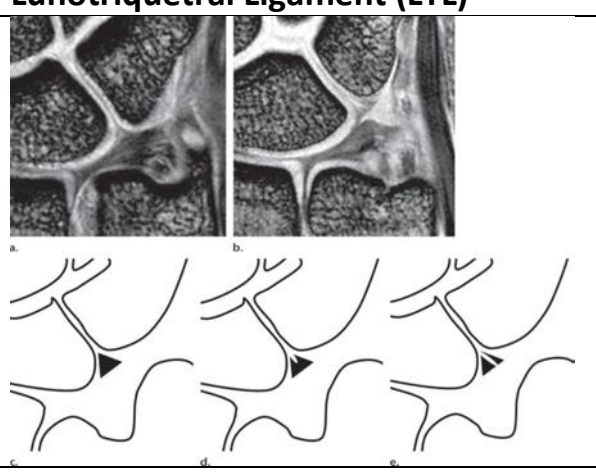
<u>Imaging Findings:</u>

- Type II lunate bone
- Chondromalacia and bone marrow chnages of the hamate bone (arrow)



Wrist Ligaments

- **<u>Extrinsic Interosseous Ligaments:</u>**
  - Dorsal Extrinsic Ligament Complex
    - Radiotriquetral
    - Dorsal intercarpal ligaments
  - Volar Extrinsic Ligament
    - Radioscaphocapitate
    - Radiolunotriquetral (long radiolunate)
    - Short radiolunate ligaments.
- **<u>Intrinsic Interosseous Ligaments</u>**
  - Scapholunate Ligament (SLL)
  - Lunotriquetral Ligament (LTL)
  - Triangular Fibrocartilage Complex (TFCC)

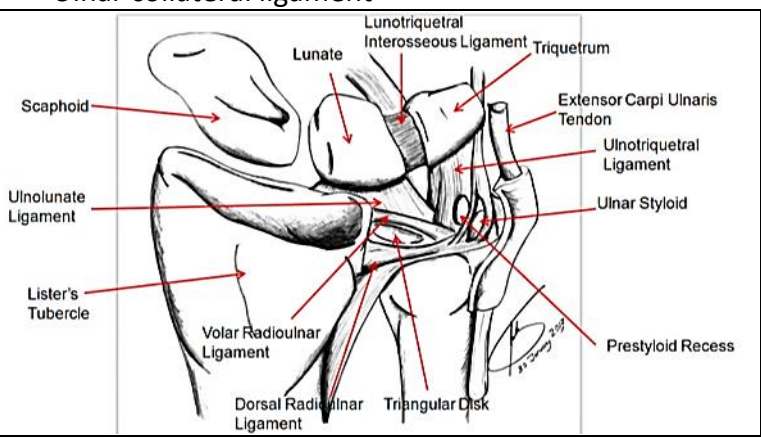
Scapholunate Ligament (SLL)	**Lunotriquetral Ligament (LTL)**
	

Triangular Fibrocartilage Complex (TFCC)

- is considered main stabilizer of distal radioulnar joint and contributor to ulnocarpal stability.

TFCC consists of

- Triangular fibrocartilage ligament (TFC) (disk proper) (straight white arrow)
  - Ulnar Fovea attachment (white arrowhead)
  - Tip of Ulnar styloid process attachment (black arrowhead)
- Ulnocarpal (ulnolunate and ulnotriquetral) ligaments. (curved white arrow).
- Meniscus homologue (triangular meniscus–like structure). (curved black arrow)
- Prestyloid recess of the joint beneath the ulnar collateral ligament (straight black arrow)
- Dorsal and volar radioulnar ligaments
- Ulnar collateral ligament



The ulnar side of Triangular fibrocartilage ligament

- The proximal lamina => attaches to the ulnar fovea (dashed arrow).
- The distal lamina => attaches to the ulnar styloid process (solid arrow)
- The region of increased signal intensity between the laminae is the ligamentum subcruentum (arrowhead).

The radial side:

- TFC is attached to the distal radial articular cartilage

The volar side:

- TFC merges with the volar radioulnar ligament which is reinforced by the ulnotriquetral and ulnolunate ligaments.

The dorsal side:

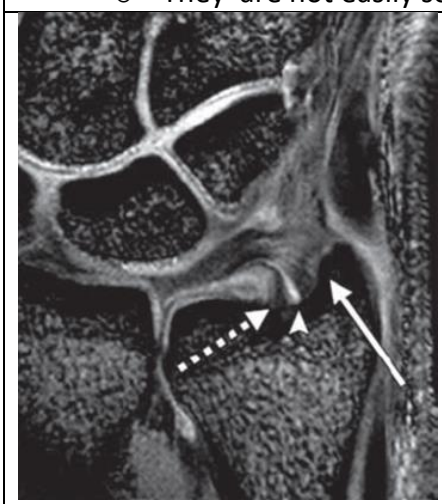
- TFC merges with the dorsal radioulnar ligament which is reinforced by the dorsal radiotriquetral ligament (dorsal radiocarpal ligament)

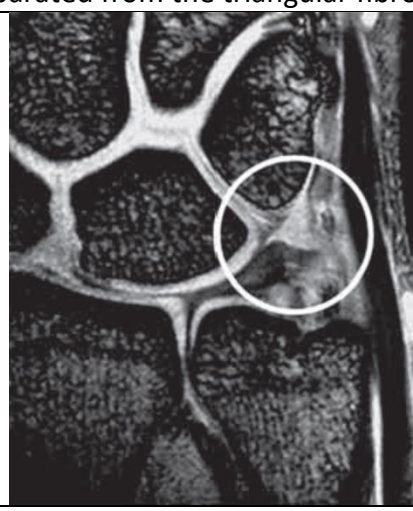
Prestyloid Recess:

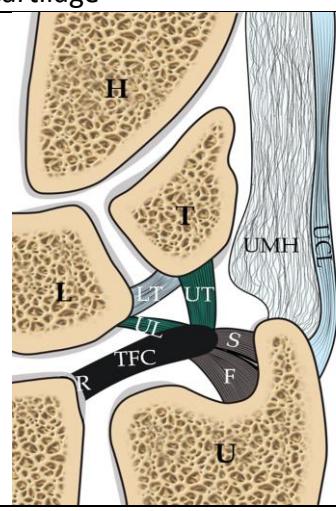
- Synovium-lined pouch with direct connection to the rest of the radiocarpal compartment.
- It is most commonly a saccular space bordered by the meniscal homologue distally, the TFCC attachments to the ulnar styloid process proximally, and the central TFCC disk radially.
- Should not be confused with a tear.

Normal appearances of TFCC

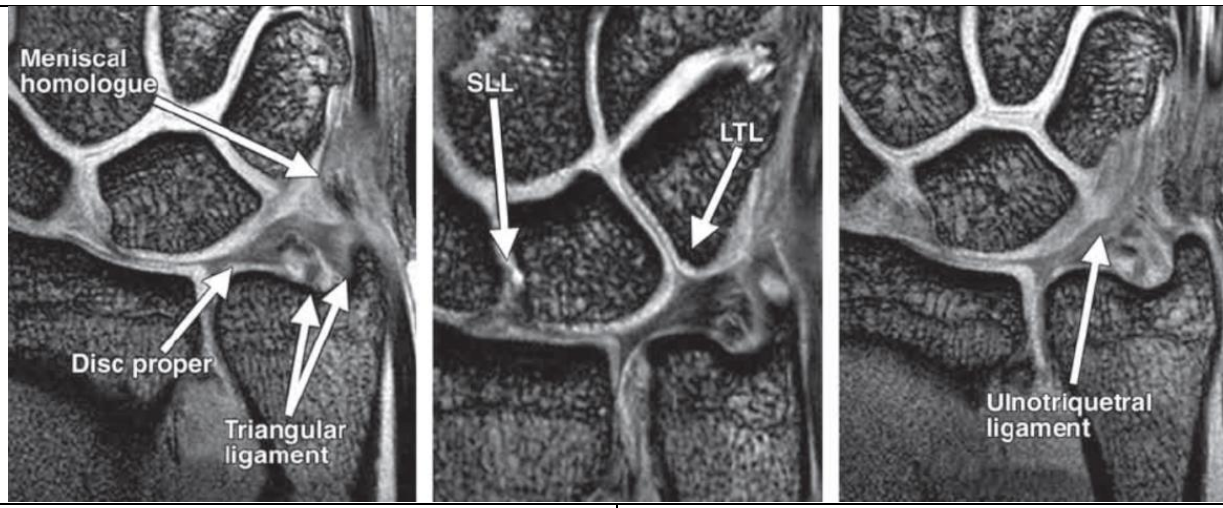
- TFC is Biconcave bowtie disc on coronal views
- Homogeneous low signal intensity on spin-echo images
- The thickness of the TFC disc depends on the degree of ulnar variance:
    - In ulnar negative wrist => TFC is thick, short and lies horizontal.
    - In ulnar positive wrist => TFC is thin, elongated and lies more vertical orientation.
- Proximal and distal laminae => striated, less homogeneous and low signal on all sequences
- Ulnomeniscal homologue is fat signal on MRI and lies just ulnar to the prestyloid recess
- The dorsal and ulnar radioulnar ligaments are most easily discerned on sagittal images
    - Striated and represent the thickest part of the margin of TFC.
    - They are not easily separated from the triangular fibrocartilage



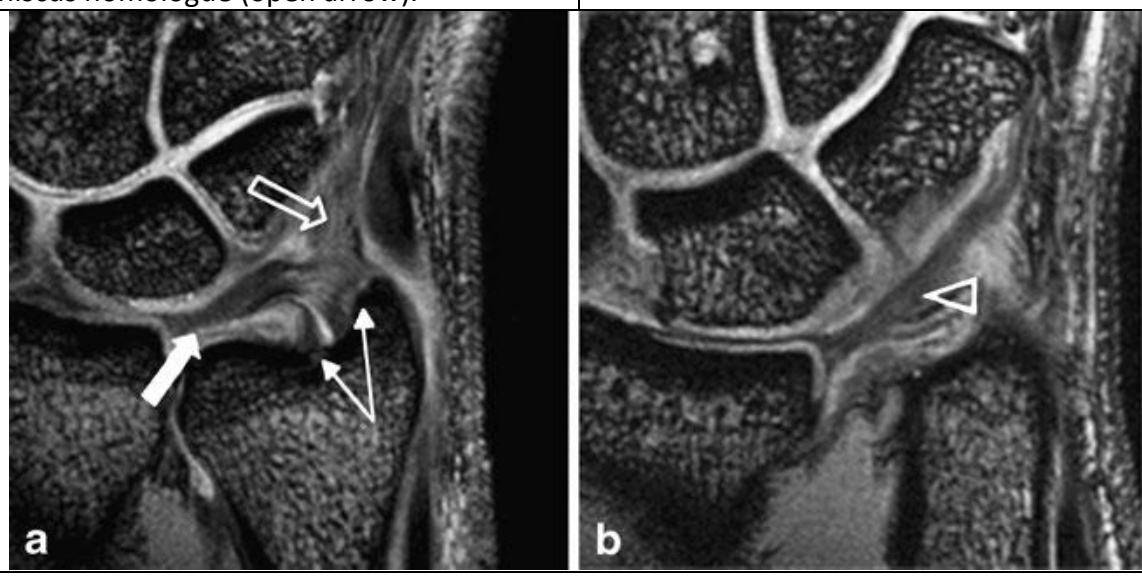




Coronal GRE

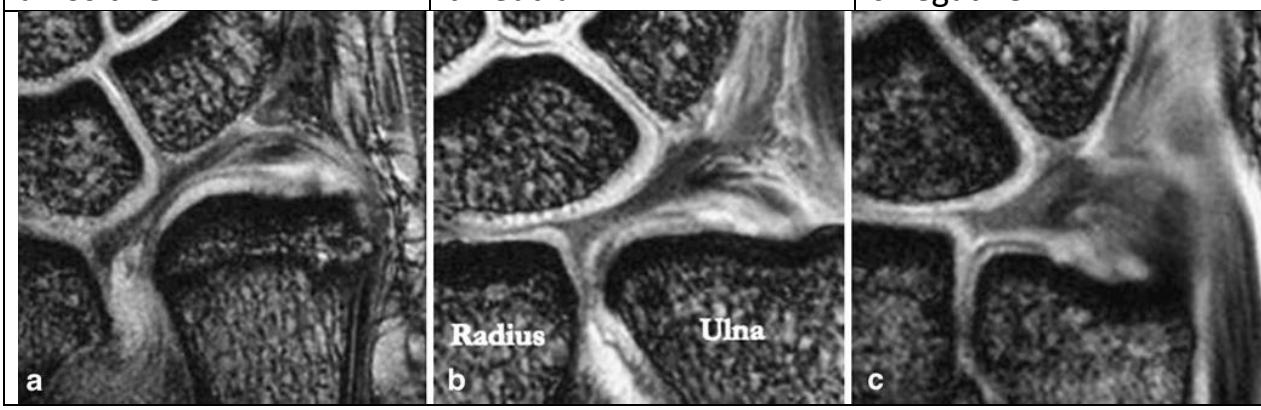


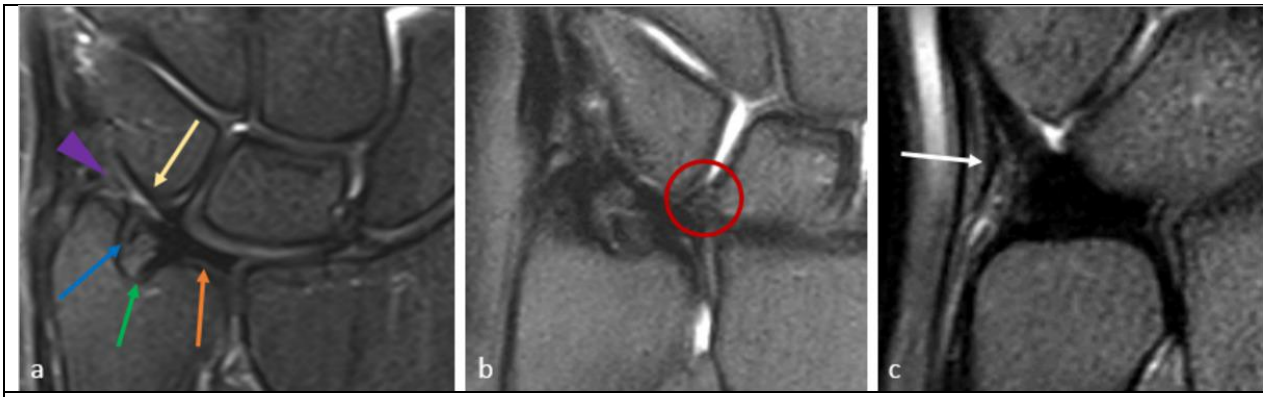
Disc proper (thick white arrow) Two laminae (thin arrows) Meniscus homologue (open arrow).	Ulnotriquetral ligament (arrowhead) is appreciated in a more volar slice



Ulnar variance correlation with TFCC

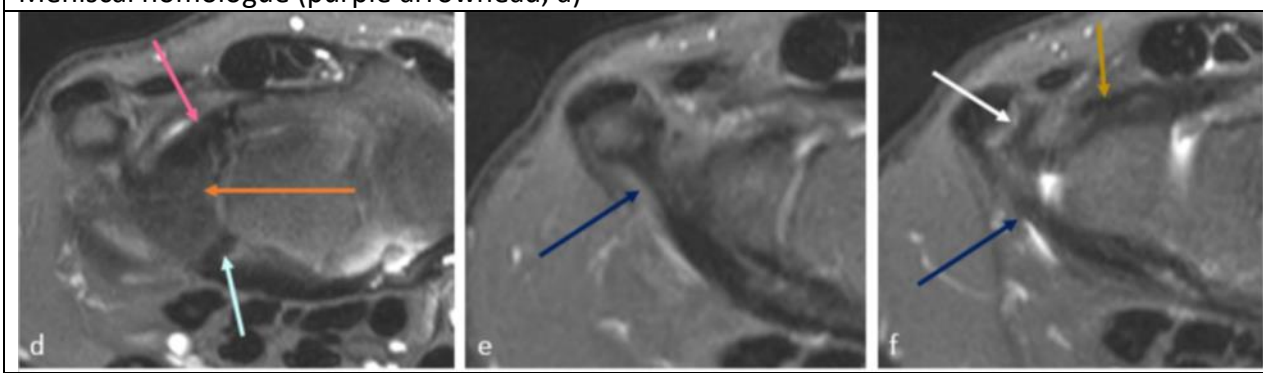
a Positive	b neutral	c negative





Coronal T2 FS images

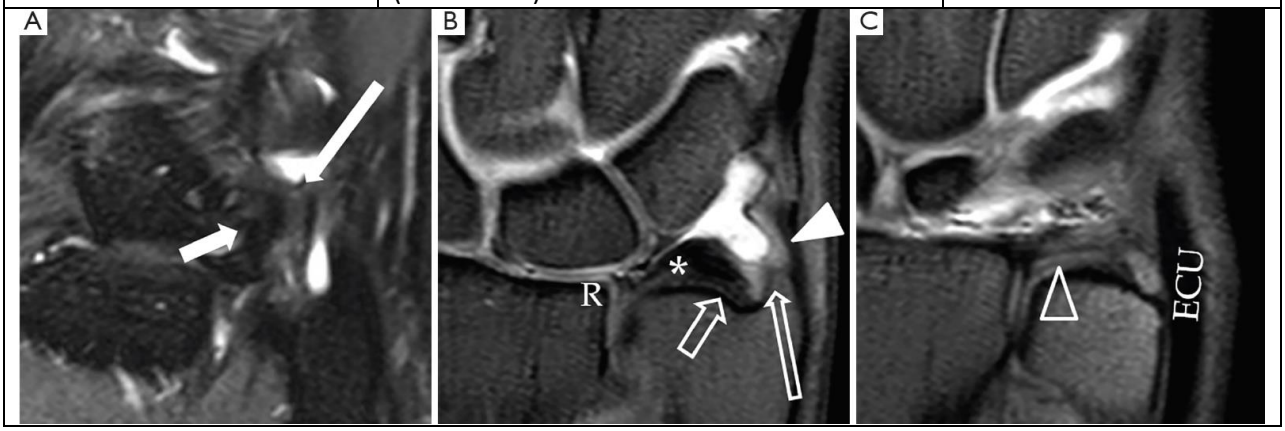
TFC proper (orange arrow, a)
Uulnoapical (blue arrow, a) and ulnobasal attachment (green arrow, a).
Ulnotriquetral ligament (yellow arrow, a)
Ulnolunate ligament (red ellipse, b)
Ulnocollateral ligament (white arrow, c)
Meniscal homologue (purple arrowhead, a)

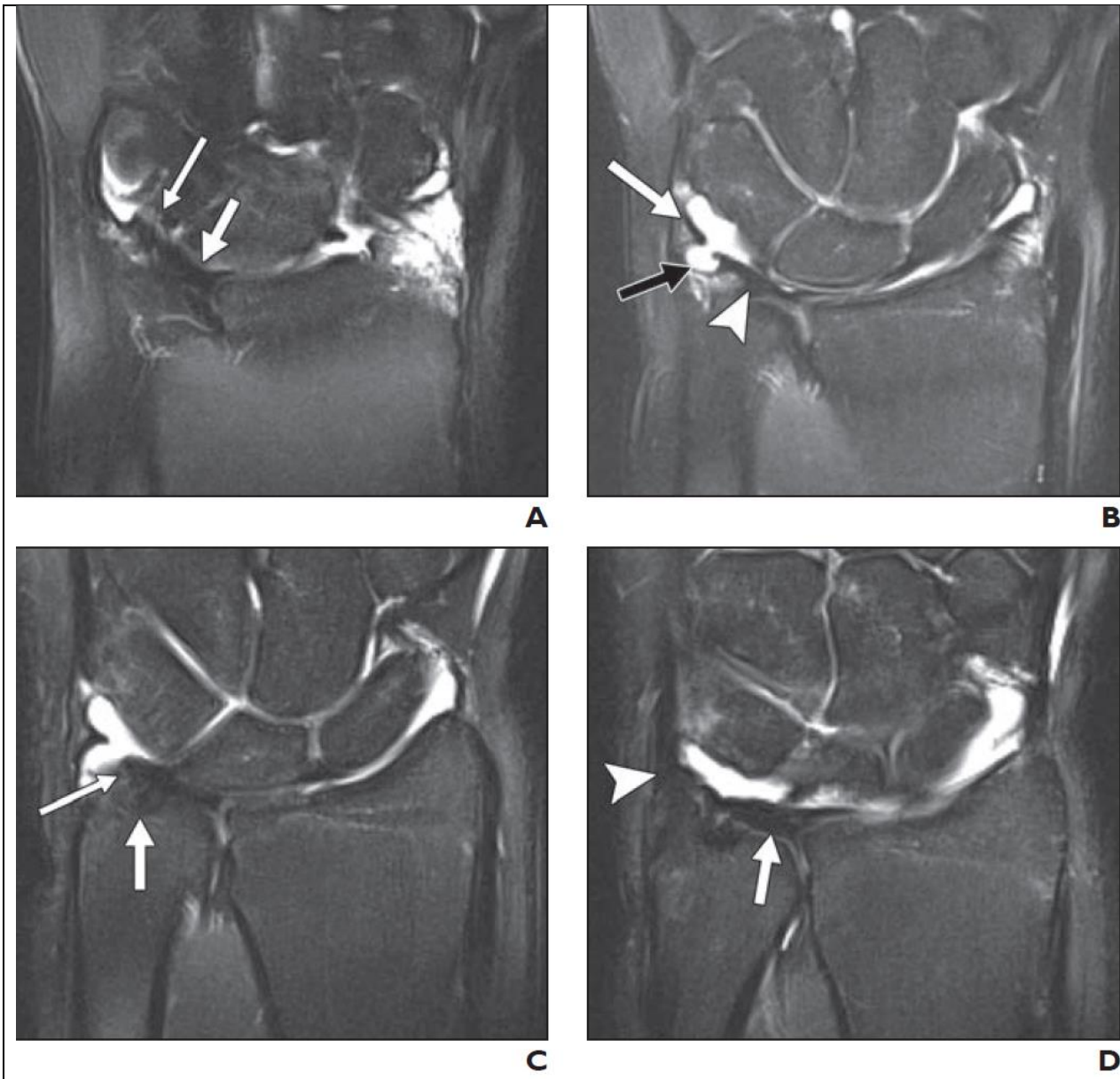


Axial T2 FS image

TFC proper (orange arrow)
Volar radioulnar ligament (light blue arrow)
Dorsal radioulnar ligament (pink arrow).
Volar ulnocarpal ligament (navy arrow, e and f)
Dorsal ulnocarpal ligament (brown arrow, f),
Ulnocollateral ligament (white arrow, f).

Coronal PD FS MR arthrography from volar to dorsal.		
Ulnotriquetral (long solid arrow) and ulnolunate ligaments (short solid arrow)	Triangular fibrocartilage articular disc (TFC) (asterisk) with radial attachment (R), foveal attachment (short block arrow), ulnar styloid process attachment (long block arrow), meniscal homologue attachment (arrowhead)	dRUL (block arrowhead) and ECU tendon sheath attachment (ECU).





Coronal T1-FS MR Arthrography image from volar to dorsal:

A) Volar radioulnar ligament (thick arrow) and ulnotriquetral ligament (thin arrow).
B) Meniscus homolog (white arrow), prestyloid recess (black arrow), and triangular fibrocartilage (TFC) (arrowhead).
C) TFC attachment to ulnar styloid tip (thin arrow) and base (thick arrow).
D) Dorsal radioulnar ligament (arrow) and extensor carpi ulnaris tendon (arrowhead).

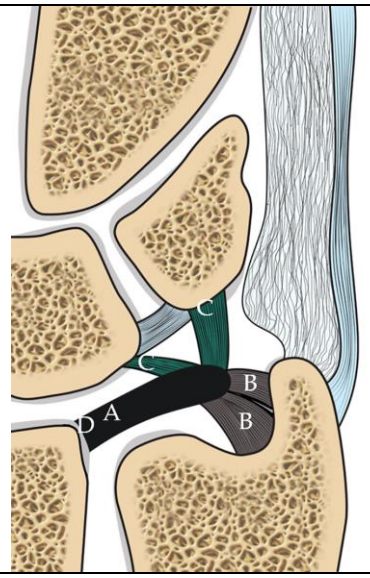
❖ Palmer Classification of TFCC abnormalities

Class I : Traumatic

A : Central perforation
B : Ulnar avulsion ± distal ulnar fracture
C : Distal avulsion (Carpal attachment)
D : Radial avulsion ± sigmoid notch fracture

Class II : Degenerative

A : TFC wear
B : A + lunate and/or ulnar chondromalacia
C : B + TFC perforation
D : C + LT ligament perforation
E : D + Ulnocarpal arthritis



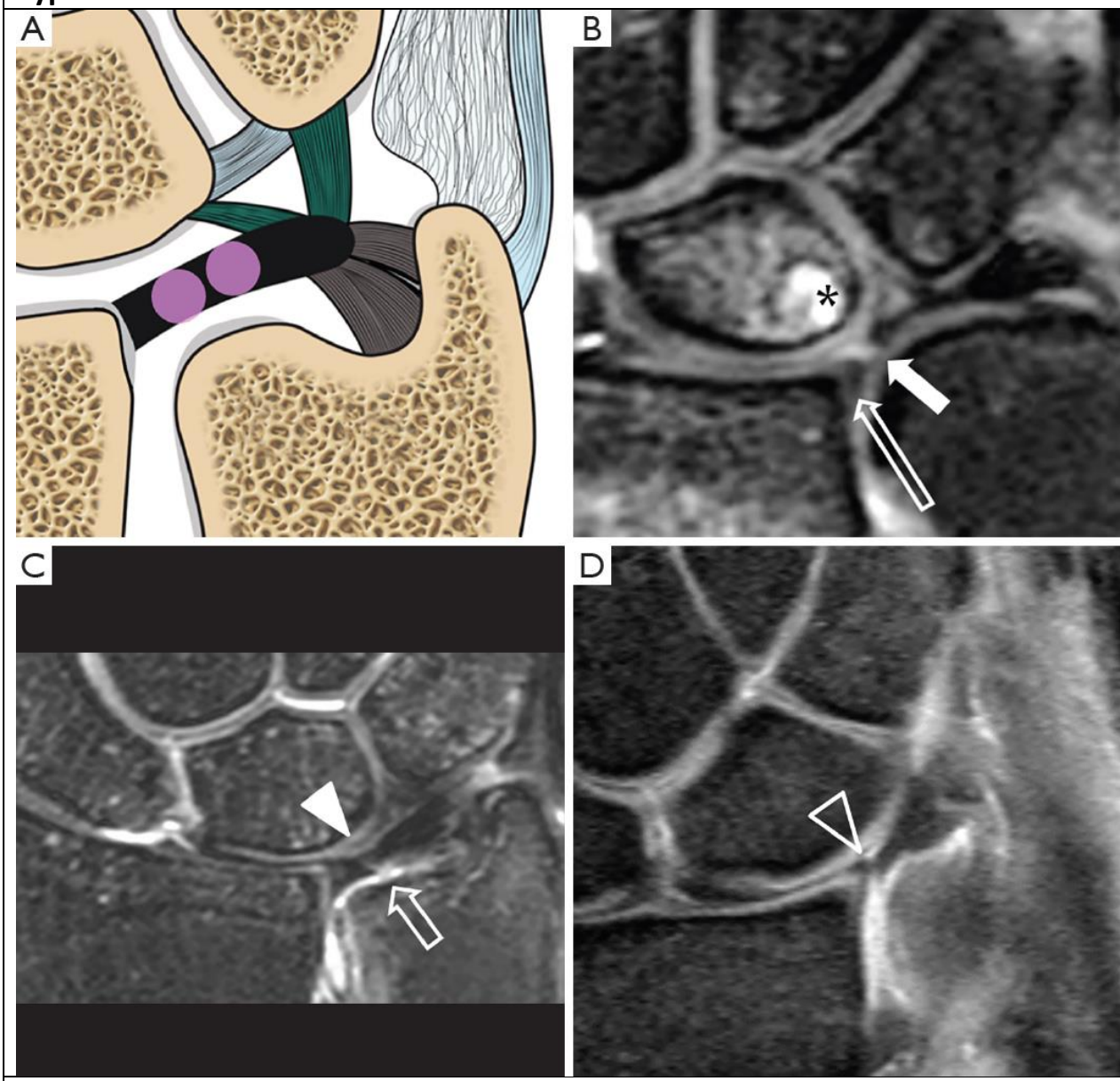
❖ MRI features of TFCC tear

- The tear can be:
  - Radial tear or named as slit-like radial or vertical
  - Horizontal
  - Combined tear or complex tear.

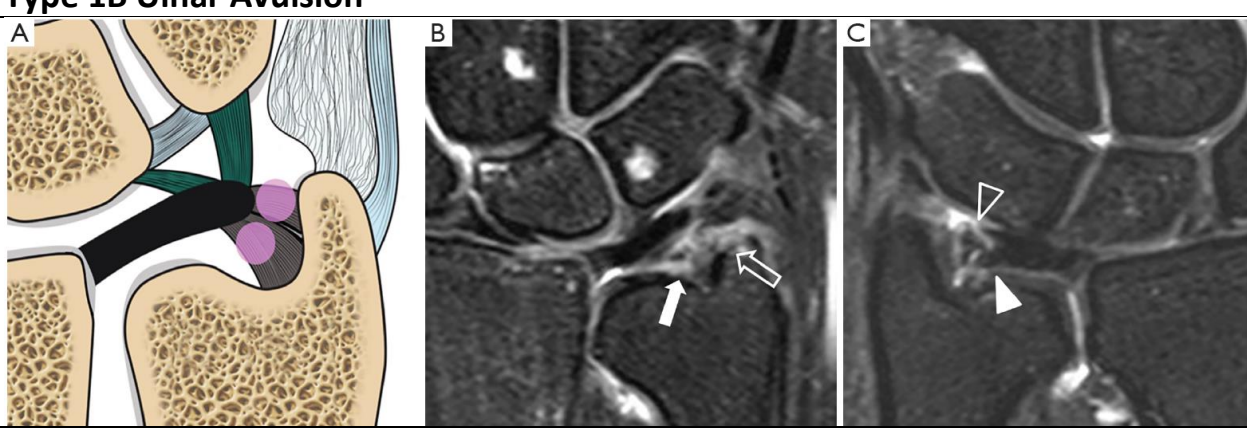
- The tear may be:
  - Grade I - Sprain: Periligamentous edema and/or increased intrasubstance fluid
  - Grade II - Partial tear: Focal fluid signal intensity or abnormal morphology of the ligament (fraying, irregularity, indistinctness, abnormal caliber)
  - Grade III - Full thickness tear: Discontinuity extending across the entire cross-section of the ligament

- It is difficult to differentiate between degenerative and traumatic tears.
- The features favouring degenerative tears include diffuse thinning of the triangular fibrocartilage, ulnar positive variant, site of tear closer to the radial attachment.

Type 1A = Central Perforation

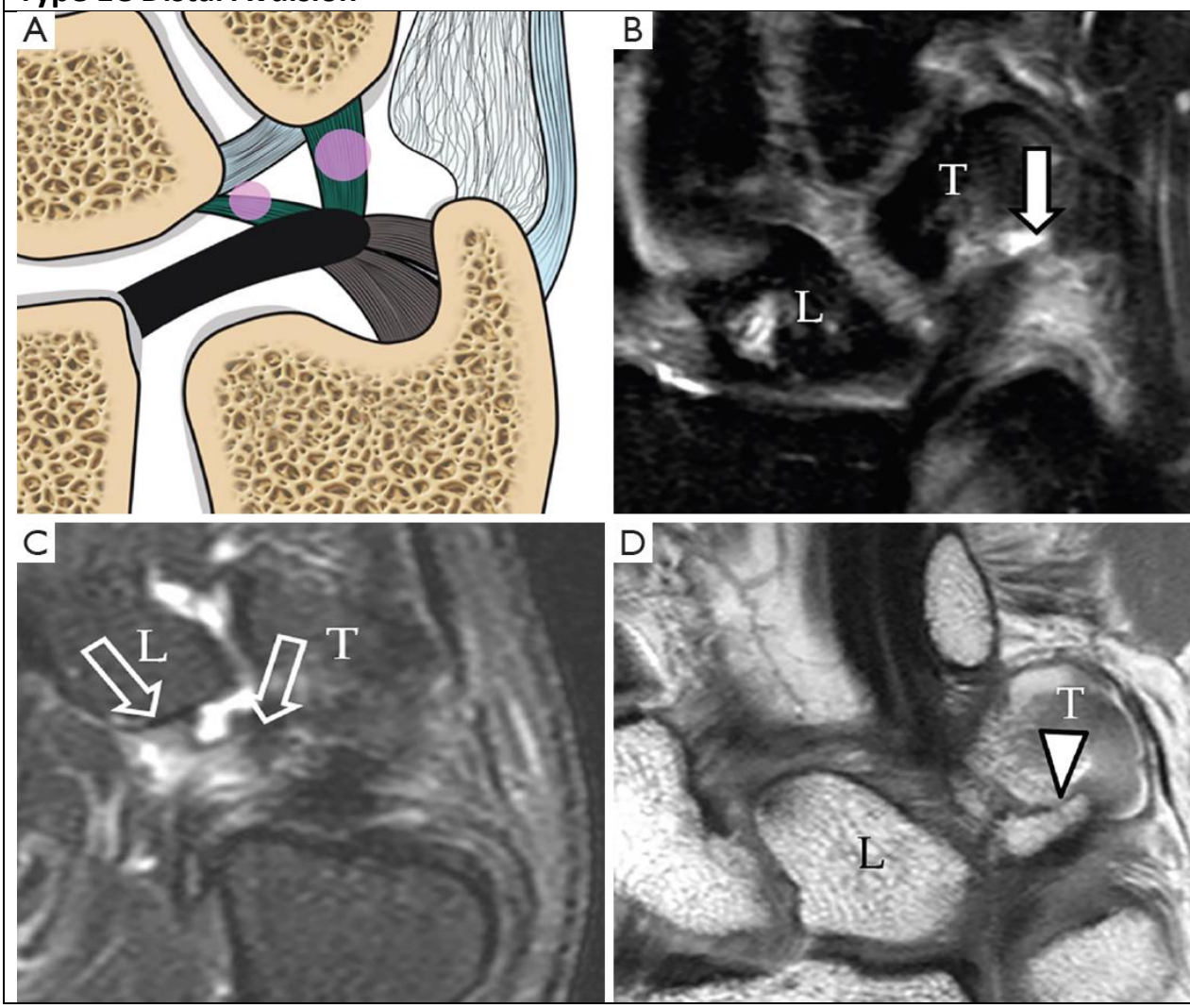


Type 1B Ulnar Avulsion

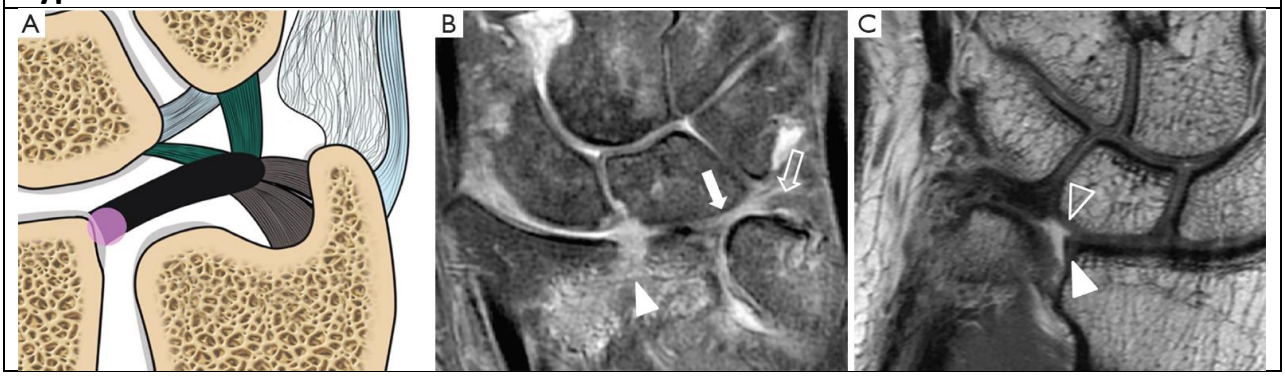


Type 1B Ulnar Avulsion + Ulnar Styloid Process Fracture

Type 1C Distal Avulsion

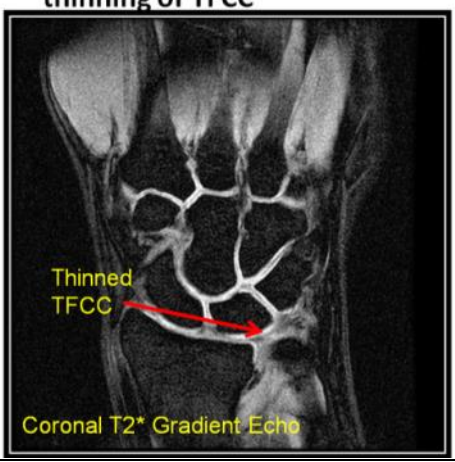


Type 1D Radial Avulsion

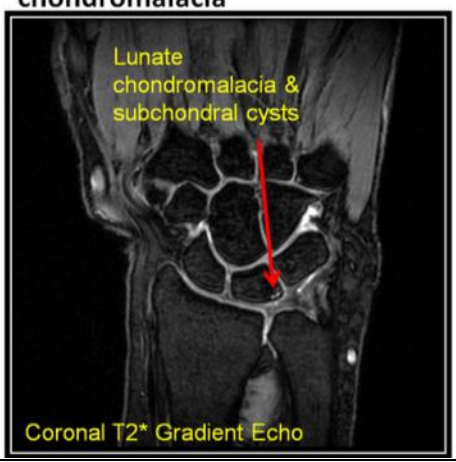


Type 2: Degeneration

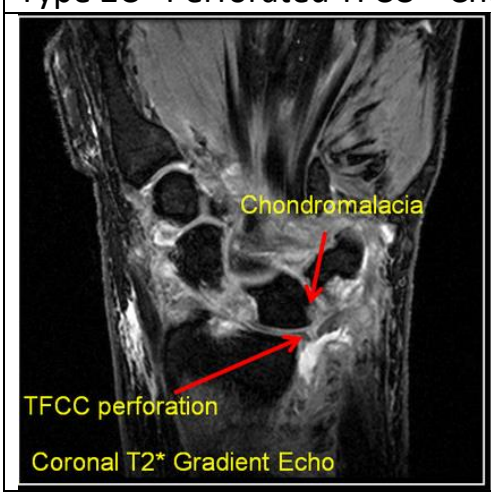
Type 2A: Degenerative thinning of TFCC



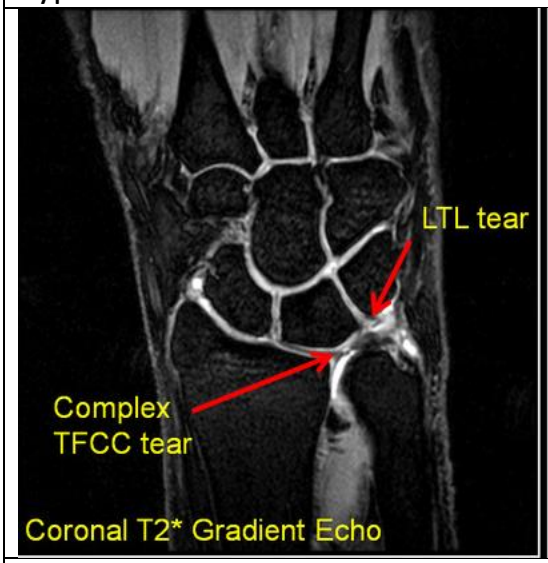
Type 2B: TFCC thinning + chondromalacia

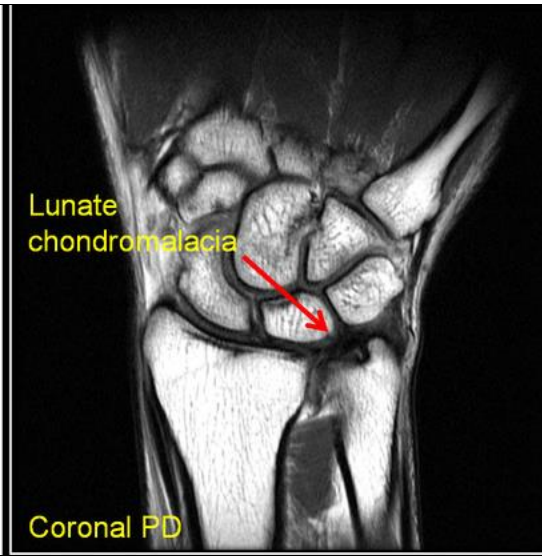


Type 2C= Perforated TFCC + Chondromalacia

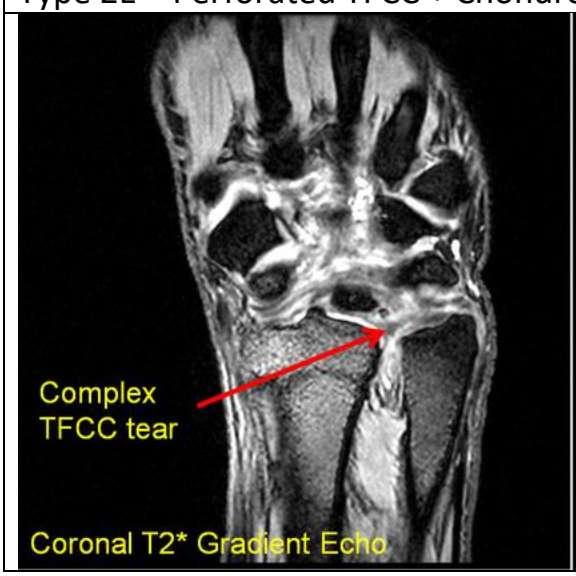


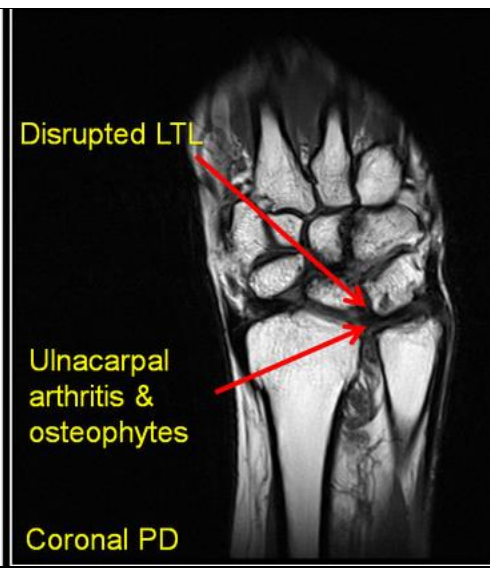
Type 2D = Perforated TFCC + Chondromalacia + Perforated LTL



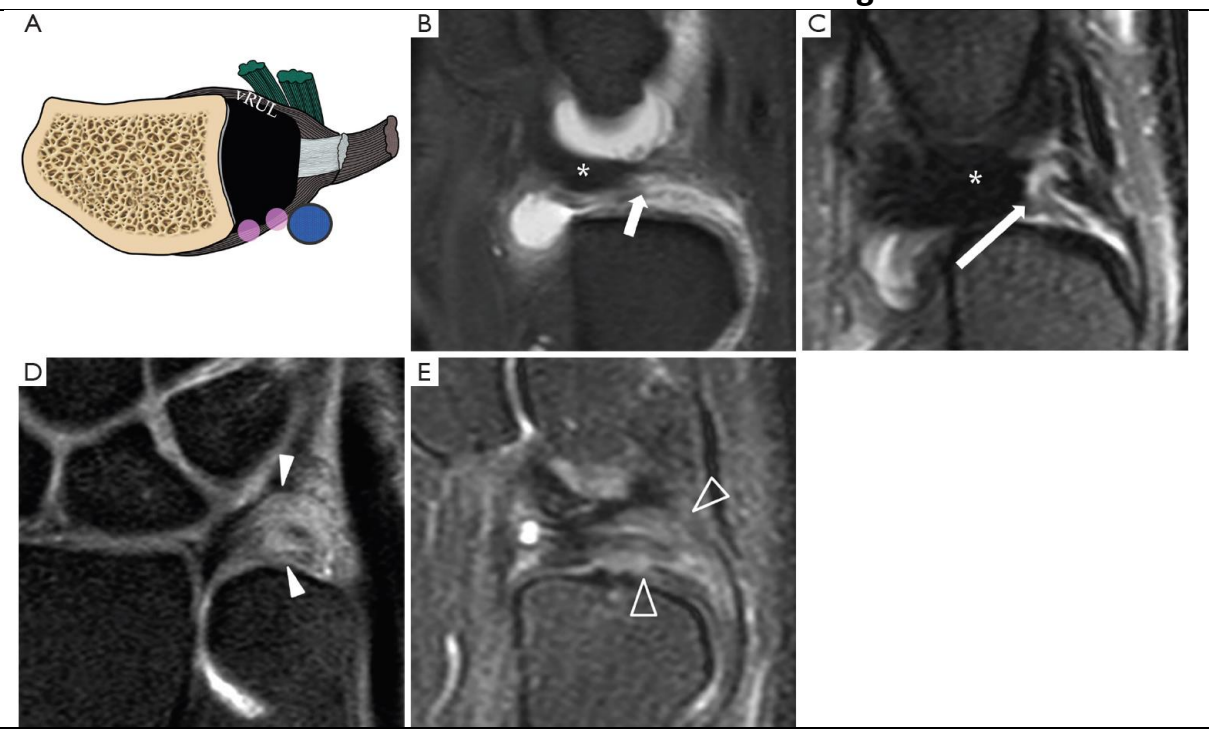


Type 2E = Perforated TFCC + Chondromalacia + Perforated LTL + secondary OA

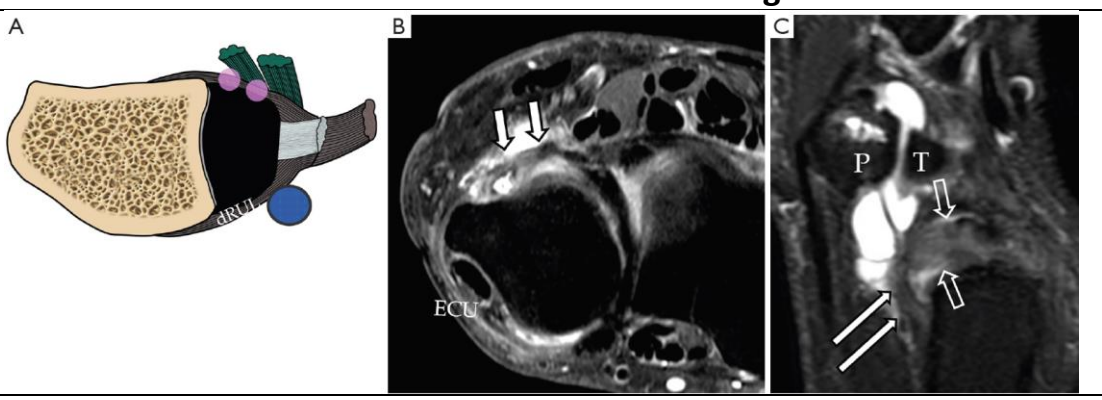




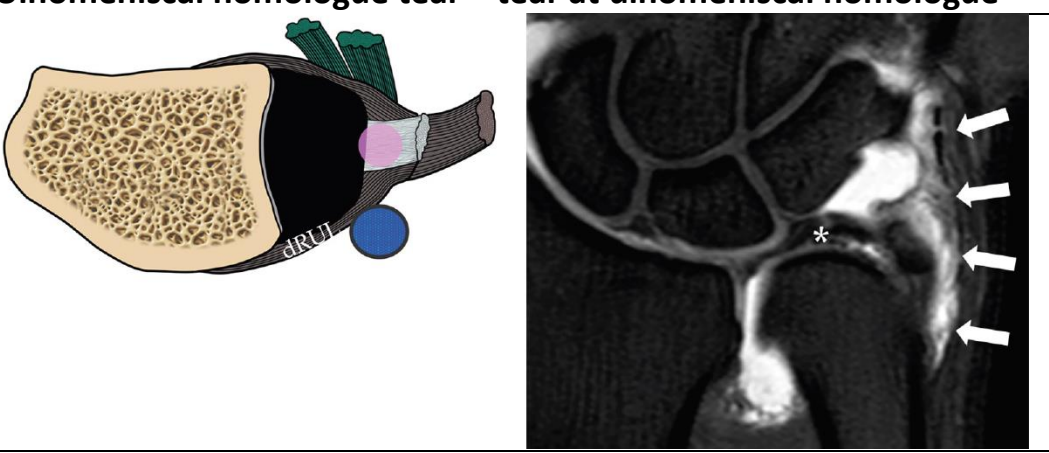
Dorsal sided TFCC tear = Tear at the dorsal radioulnar ligament



Volar sided TFCC tear = Tear of volar radioulnar ligament



Ulnomeniscal homologue tear = tear at ulnomeniscal homologue

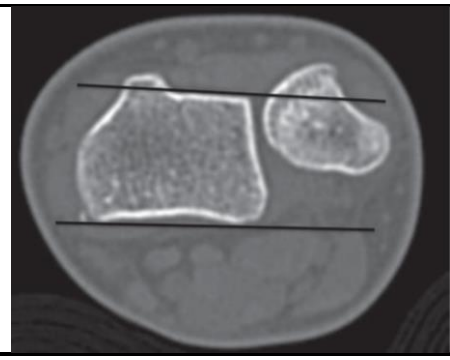


Distal Radioulnar Joint Instability

Subluxation and Dislocation

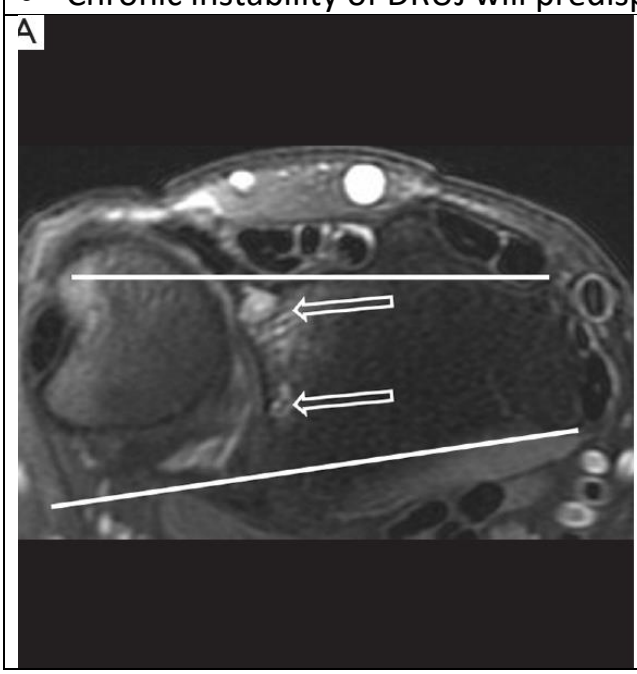
❖ The Mino (or radioulnar line) method

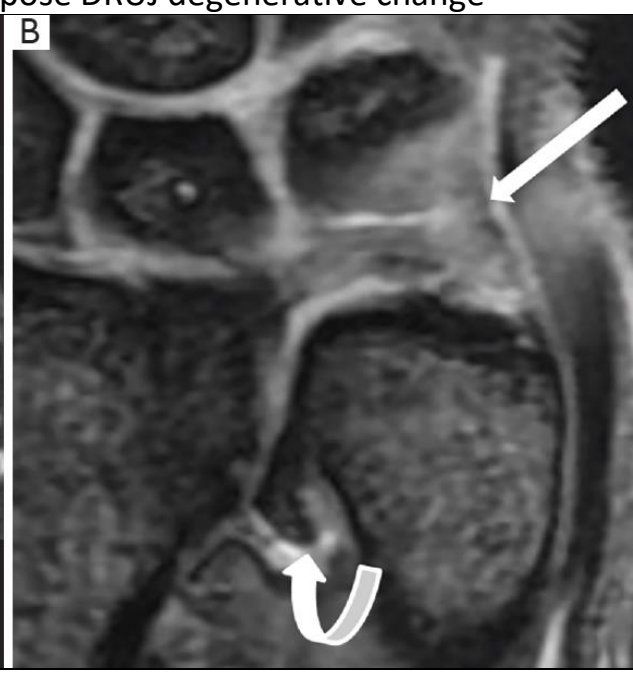
- Drawing a line through both the volar and dorsal margins of the distal radius, which is extended through the ulnar head.
- Instability is present if more than 25% of the head of the ulna lie volar or dorsal to these lines



❖ Dorsal Subluxation Of DRUJ

- Dorsal displacement of the ulnar head relative to the sigmoid notch of the distal radius with non visualization of the palmar distal radio-ulnar ligament.
- Chronic instability of DRUJ will predispose DRUJ degenerative change



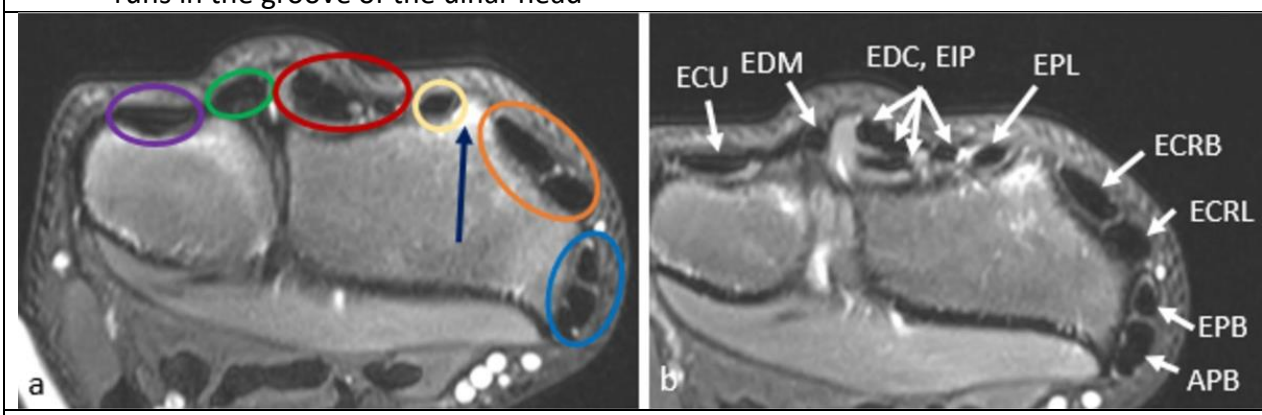


Tendon Injury

❖ Extensor Tendons

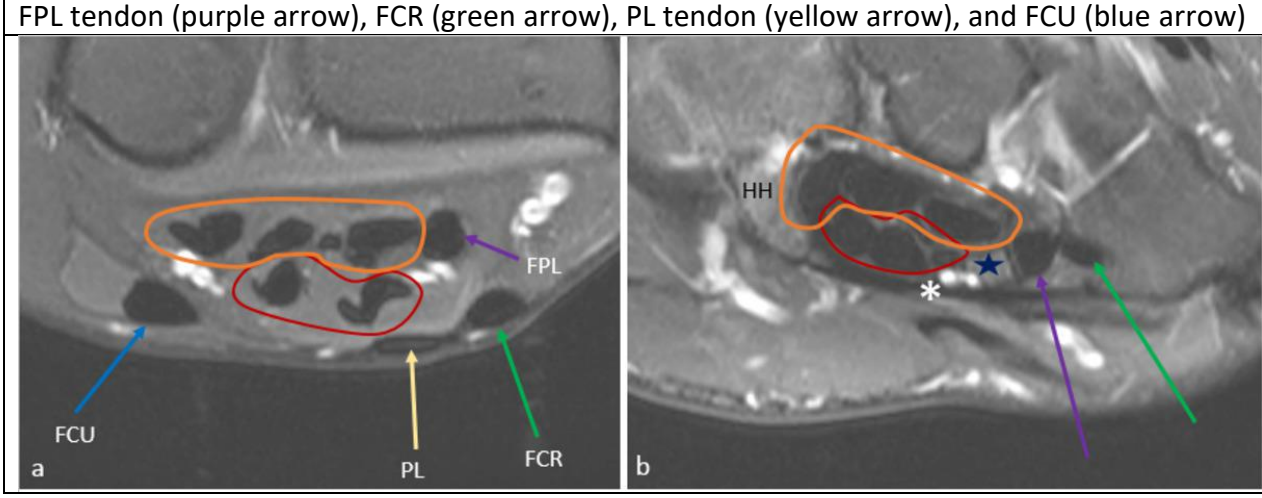
6 extensor compartments:

I: extensor pollicis brevis, abductor pollicis longus
II: extensor carpi radialis longus, extensor carpi radialis brevis
III: extensor pollicis longus
compartments 2 and 3 are divided by Lister's tubercle of the distal radius
IV: extensor digitorum, extensor indicis
V: extensor digiti minimi
VI: extensor carpi ulnaris
runs in the groove of the ulnar head



❖ Flexor Tendons

FDP tendons (orange ellipse) course deep to the FDS tendons (red ellipse).
FPL tendon (purple arrow), FCR (green arrow), PL tendon (yellow arrow), and FCU (blue arrow)



❖ De Quervain's Tenosynovitis

- Painful stenosing tenosynovitis involving the first extensor (dorsal) tendon compartment of the wrist (typically at the radial styloid).
- This compartment contains the abductor pollicis longus (APL) and extensor pollicis brevis (EPB) tendons.

- De Quervain tenosynovitis is the second most common entrapment tendinopathy in the hand following trigger finger.
- Middle-aged individuals
- More common in women (~80% of cases).
- Most cases are associated with overuse

Tenosynovitis:

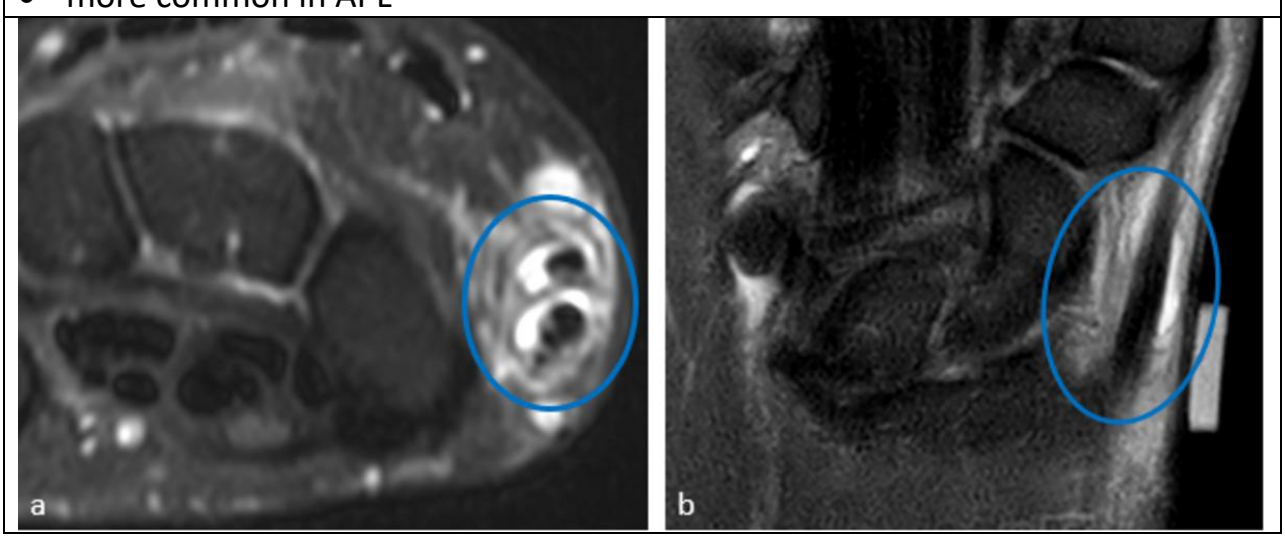
- Increased fluid within APB and EPB tendon sheaths (blue ellipses).
- Thickened oedematous retinaculum
- Surrounding reactive soft tissue or marrow edema

Tendinosis

- Tendon enlargement maximal at radial styloid
- Increased intratendinous T2 signal compared to other tendons

Longitudinal Tendon Tear

- Linear high T2 signal due to fluid within the split
- more common in APL

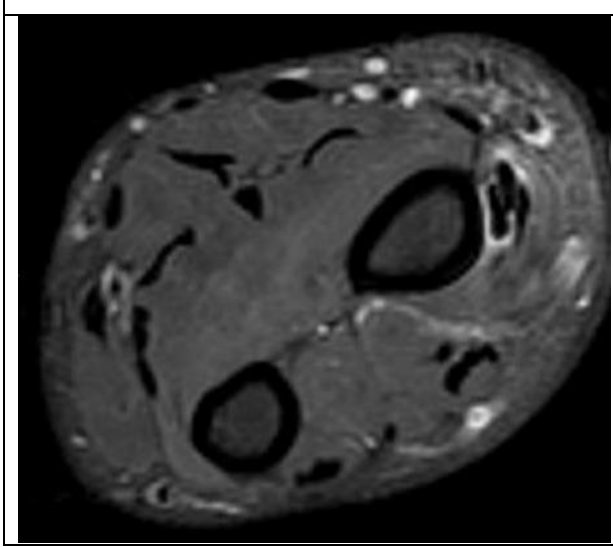


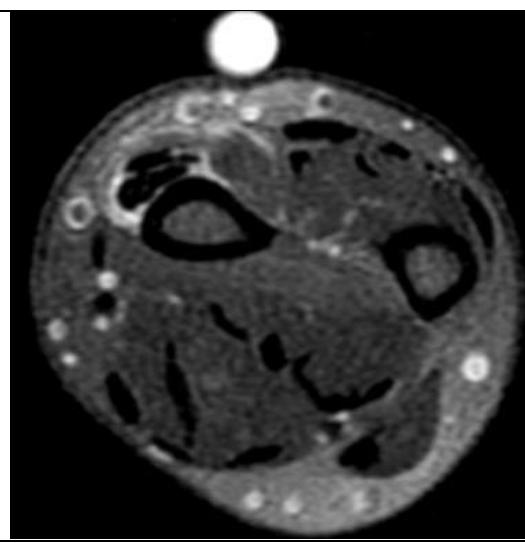
❖ Intersection Syndrome

- Overuse tenosynovitis that occurs around the intersection of :
  - **1st** extensor compartment (abductor pollicis longus and extensor pollicis brevis)
  - **2nd** extensor compartment (extensor carpi radialis longus and extensor carpi radialis brevis).
- It occurs within the forearm proximal to the location of the more common condition De Quervain tenosynovitis.

MRI Findings:

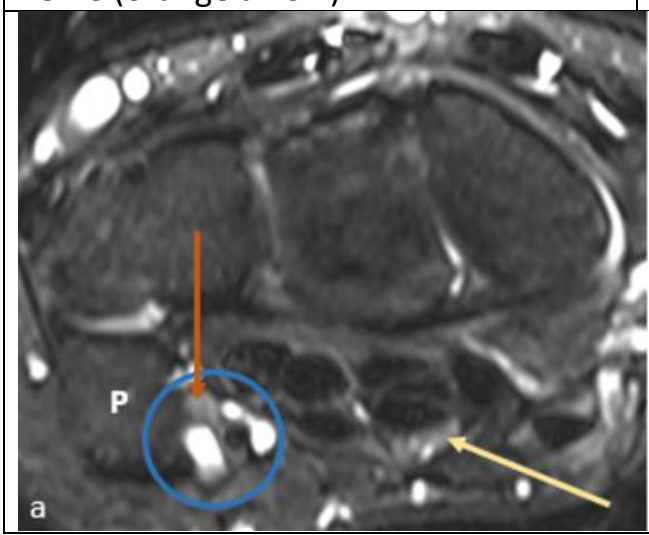
- Peritendinous oedema concentrically surrounding the second and first extensor compartments centered around the point of crossover ~4 cm proximal to the Lister tubercle.

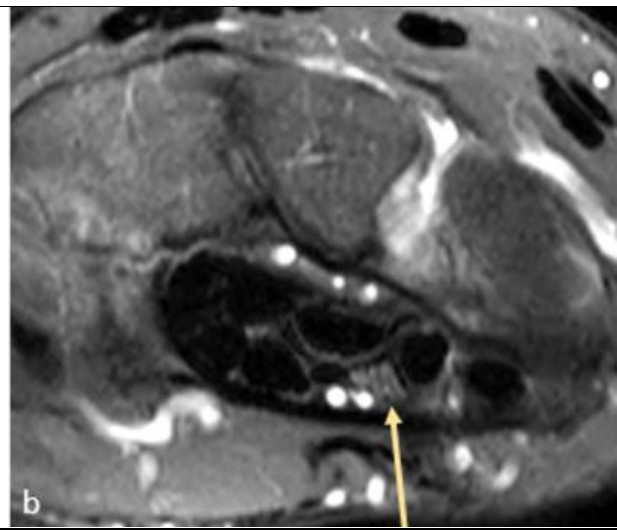




NERVE INJURY

Guyon's canal (blue ellipse) adjacent to the pisiform (P) contains the ulnar nerve (orange arrow).	The median nerve is identified within the carpal tunnel (yellow arrow).





A- Carpal Tunnel Syndrome

- Compression of the median nerve at the wrist.
- The most common entrapment neuropathy in the upper limb

The carpal tunnel is formed by

The transverse carpal ligament
The volar surface of the carpal bones.
The median nerve lies immediately deep to the transverse carpal ligament.

Clinical Picture:

Sensory: paresthesia of the thumb and radial aspect of the ring finger.
Motor: atrophy of the thenar and loss of abduction and opposition of the thumb.

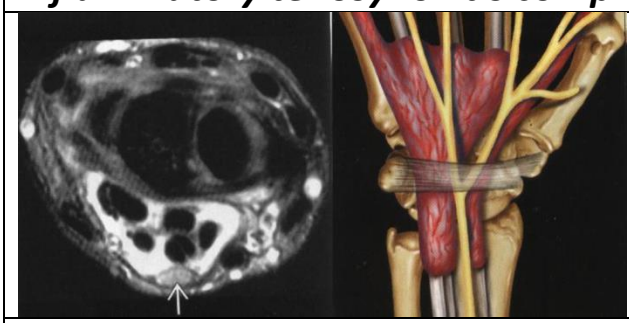
Normal Median Nerve at axial image:

- Median nerve is rounded or ovoid structure
- Intermediate signal on T1 and T2.
- It is flattened at the level of pisiform

Abnormal Median Nerve at axial image:

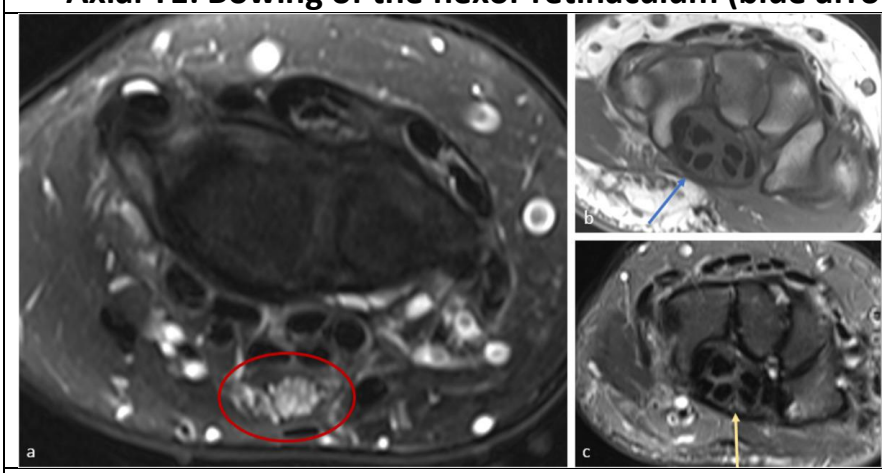
- Swollen nerve at the level of pisiform or flattened at the level of hamate.
- Increased T2 FS/STIR signal of the nerve.
- Palmar bowing of the flexor retinaculum at the level of hamate (>2 mm beyond a line connecting the pisiform and the scaphoid).
- Abnormal signal of the thenar muscles

Inflammatory tenosynovitis compressing the median nerve

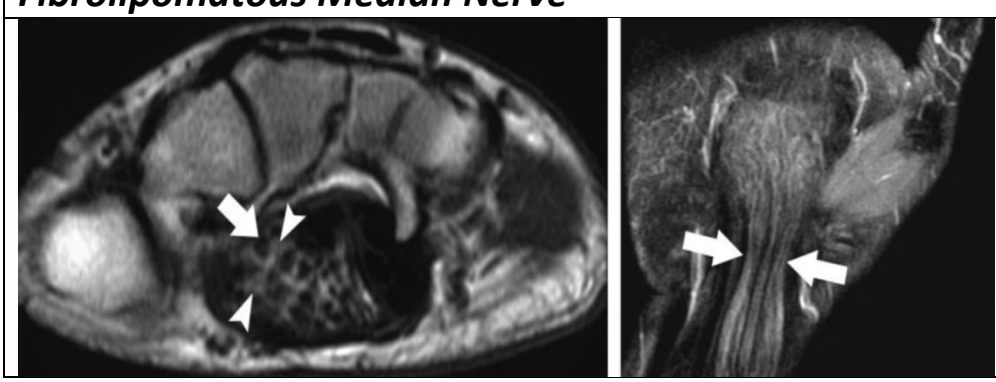


✓ **Axial T2 FS: The median nerve is enlarged and increased in T2 signal**

✓ **Axial T1: Bowing of the flexor retinaculum (blue arrow).**



Fibrolipomatous Median Nerve

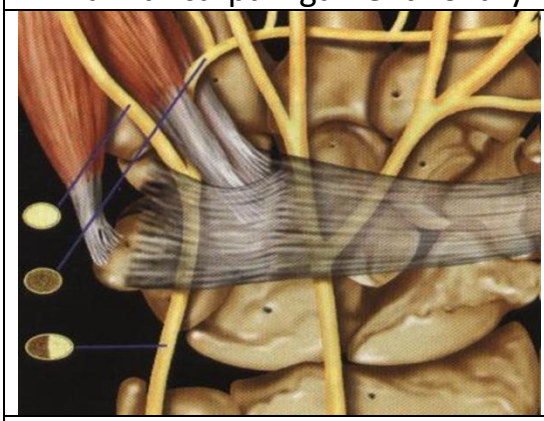


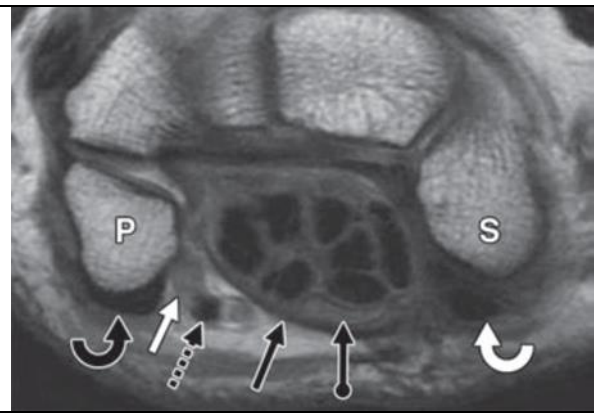
B- Guyon Canal Syndrome

❖ *Ulnar Tunnel Syndrome = Guyon Canal Syndrome*

A fibro-osseous canal (curved white arrow) formed by:

- Pisiform bone medially
- Flexor retinaculum dorsally
- Palmar carpal ligament vollary.

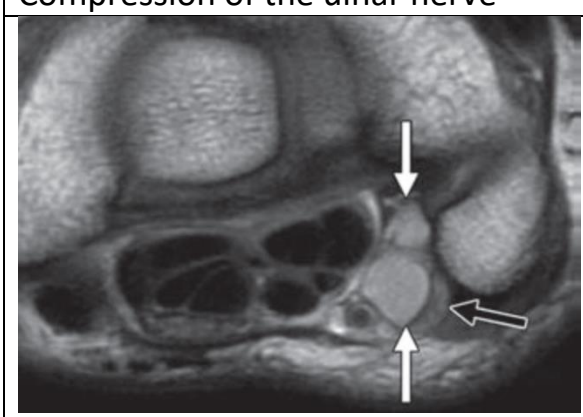




Clinical Picture:

- Pain and tingling along hypothenar and ulnar aspect of 4th and 5th fingers
- Weakness of the hypothenar muscles.

Ganglion cyst in Guyon Canal => Compression of the ulnar nerve



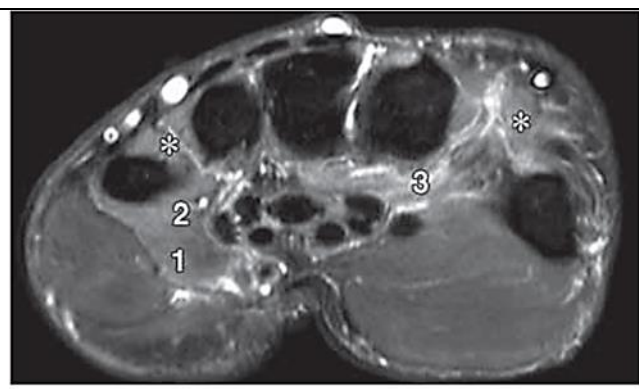


Figure 14. Distal ulnar nerve denervation pattern in a 49-year-old man with Guyon canal syndrome. Axial STIR MR image (4528/30) of the left hand shows abnormal hyperintensity of the muscles innervated by the distal ulnar nerve. *1* = flexor digiti minimi, *2* = opponens digiti minimi, *3* = adductor pollicis, * = interosseous muscles.

Madelung Deformity

- Due to premature closure or defective development of ulnar third of distal epiphysis of radius.

Associations

- Turner syndrome: metacarpal bones shortening (especially 4th) and decreased carpal angles

Radiological Findings:

- **Dorsal and radial bowing of the radius**
- Exaggerated palmar (up to 35°) and ulnar tilt (up to 60°) of the radiocarpal articulation
- Failure of ossification of the ulnar side of the distal radial epiphysis
- Exaggerated radial inclination
- Decreased carpal angle below 118°(normal from 118° to 139°).
- Carpal subluxation in a palmar and ulnar direction
- Lunate is gradually forced to the apex of the v-shaped radio-ulnar-carpal joint
- "**V-shaped" proximal carpal row** = herniated proximal carpal row.
- Dorsal subluxation of the distal radio-ulnar joint
- Positive ulnar variance
- Wedging of the carpus between the radius and ulna

Distal Radial Fractures

1) Colles Fracture

- Most common type of distal radial fracture
- Secondary to a fall on an outstretched hand (FOOSH)
- Adult age group
- Elderly women

Radiological Findings:

- Extra-articular transverse distal radial fracture
- Dorsal angulation and displacement of the distal fracture fragment
- Impaction with resultant shortening of the radius
- An associated ulnar styloid fracture

Complications:

- Silver fork deformity
- Radial shortening and loss of radial inclination resulting in distal ulna abutting the lunate (Ulnar impingement syndrome)

2) Smith Fracture

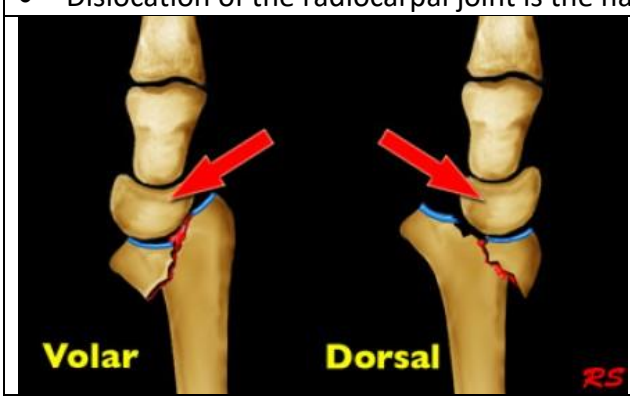
- Reverse Colles fracture.
- Fall onto a flexed wrist

Radiological Findings:

- Extra-articular transverse distal radial fracture
- Volar angulation of the distal fracture fragment

3) Barton Fracture

- Volar-type Barton's = fracture-dislocation of volar rim of radius. (most common).
- Dorsal-type Barton's = fracture-dislocation of dorsal rim of radius.
- Extend through the articular surface
- Dislocation of the radiocarpal joint is the hallmark of Barton's fractures.

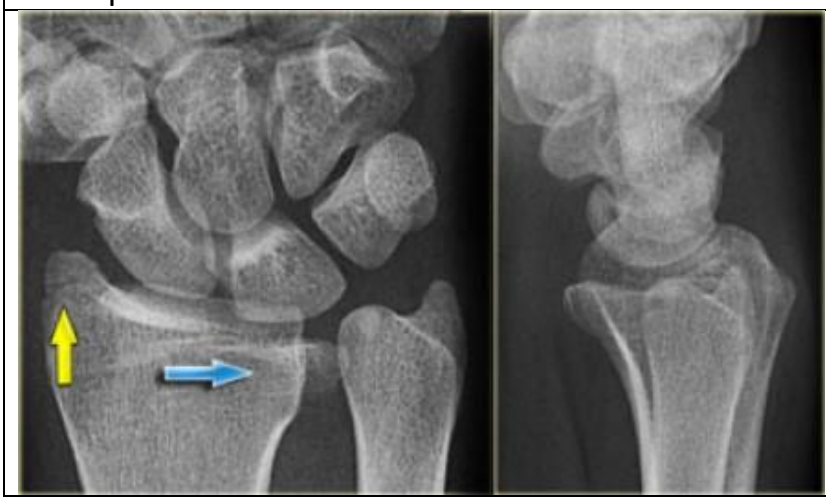


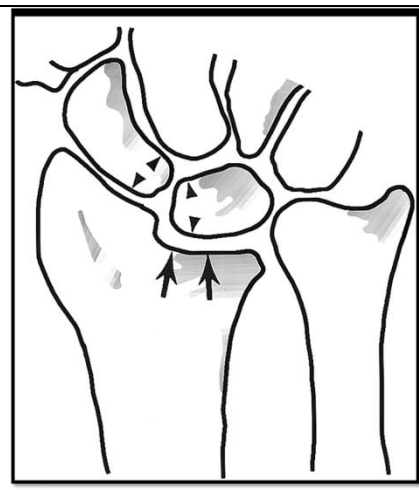
4) Chauffeur Fracture = Hutchinson Fracture

- Intra-articular fractures of the radial styloid process.
- associated injury to the scapholunate ligament

5) Die-Punch Fracture

- Depression fracture of the lunate fossa of the distal radius.





Fractures in Children

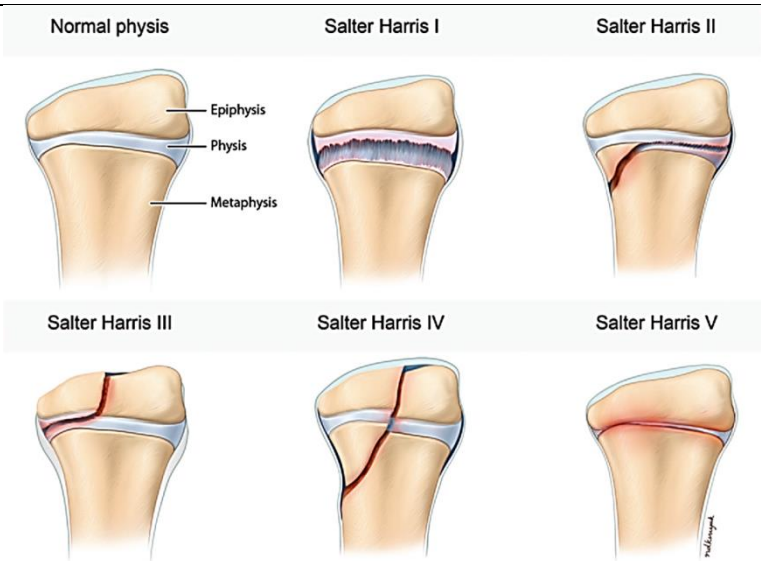
1) Torus Fracture = Buckle Fracture

- Subtle deformity or buckle of the cortex

2) Green Stick Fracture

- Partial fractures, since only one part of the bone is broken and the other side is bent

3) Physeal Fracture:



Salter-Harris type I

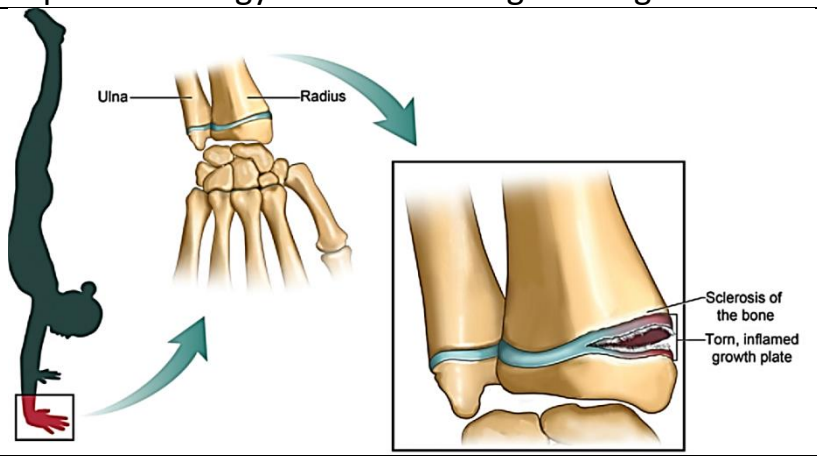
Salter-Harris type II

Salter-Harris type III

Salter-Harris type IV

4) Gymnast Wrist

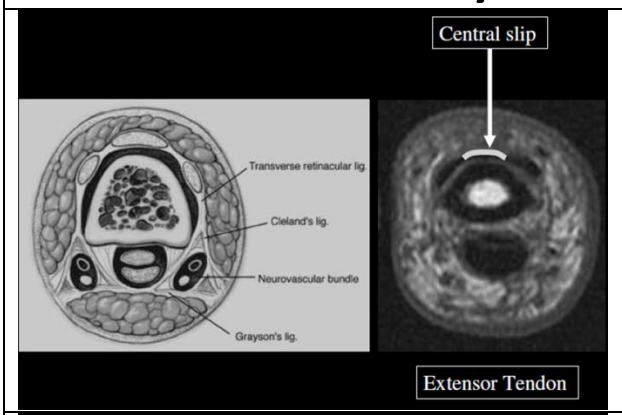
- Chronic Overuse Injuries
- Chronic Salter-Harris I fracture of the distal radius
- High-impact sport such as gymnastics or weight lifting

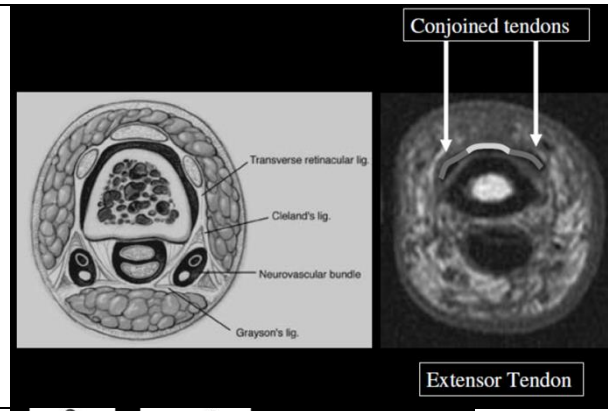


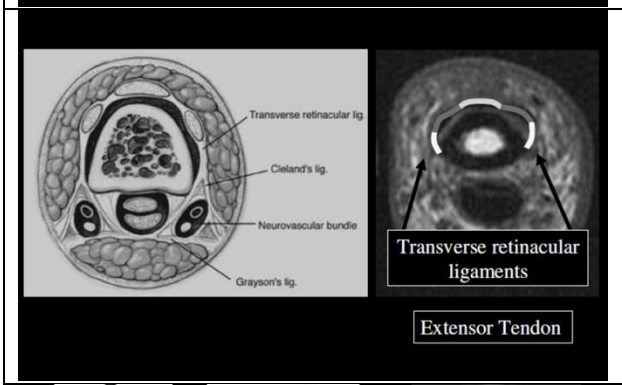
Distal Radial physis widening + Irregularity + Sclerosis

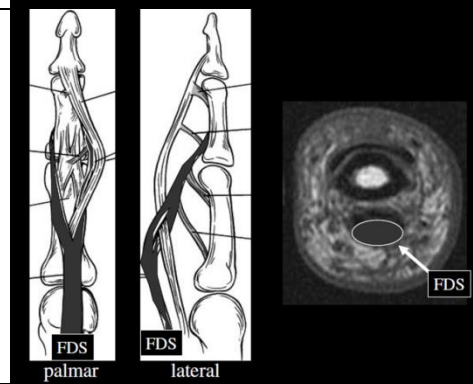
Hand & Thumb

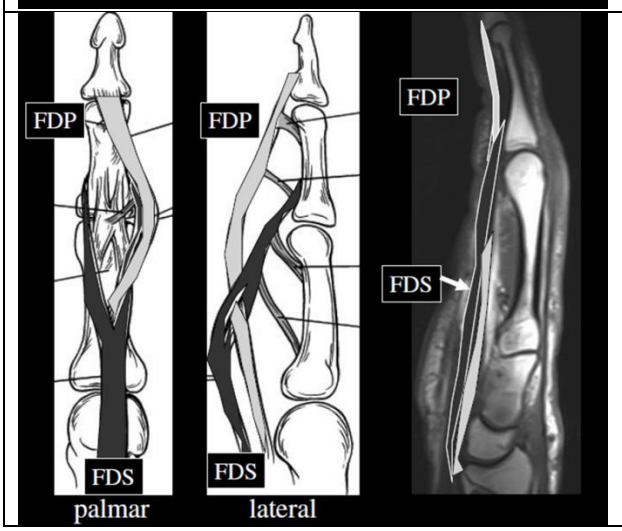
❖Normal Anatomy

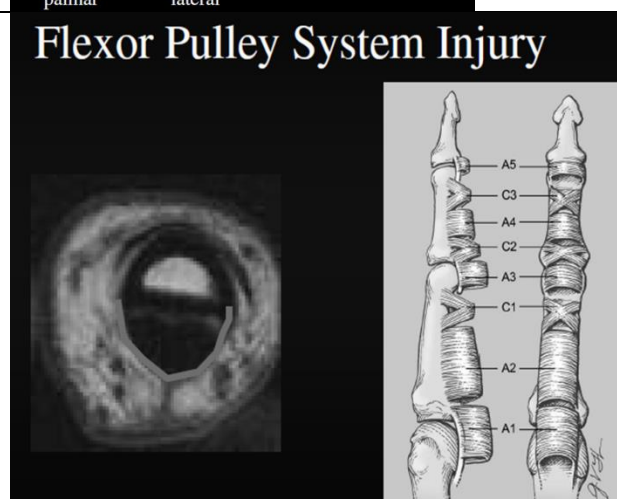




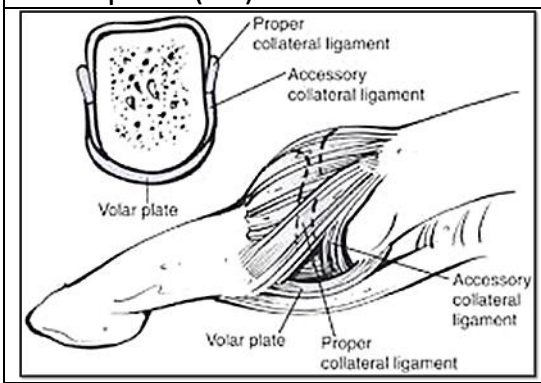
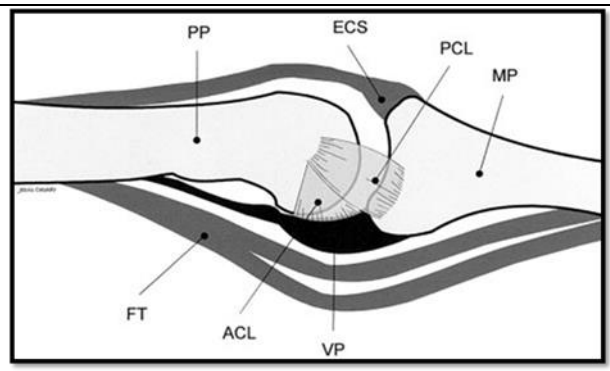
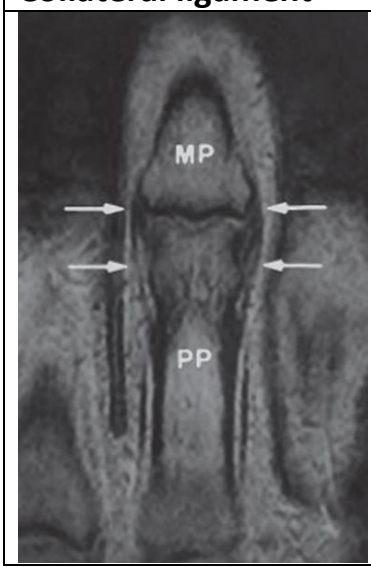






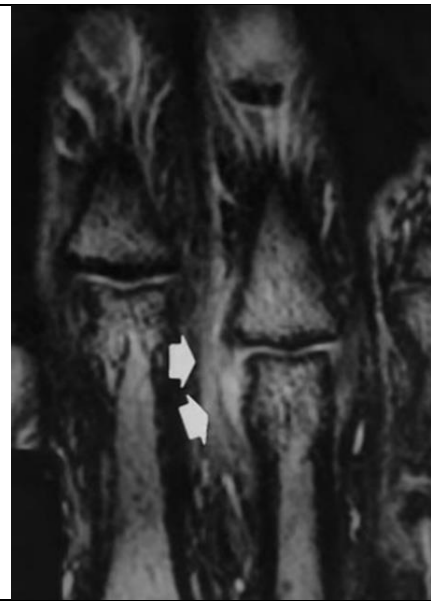


Interphalyngeal & Metacarpo-phalyngeal Joints

Proper collateral ligament (PCL) Accessory collateral ligament (ACL Volar plate (VP).	
	
Collateral ligament	**Volar Plate**
	

A- Collateral Ligament Injury

- Abducting or adducting force is applied to the PIP joint while the finger is extended



3 main injuries may occur:

- Ligamentous sprain with no loss of articular stability
- Partial ligamentous tear with laterolateral articular instability
- Complete ligamentous rupture with major instability and articular luxation.

Imaging findings:

- Complete interruption of the ligamentous fibers
- Intra- and periligamentous high signal intensity secondary to edema and hemorrhage
- Extravasation of intraarticular fluid.

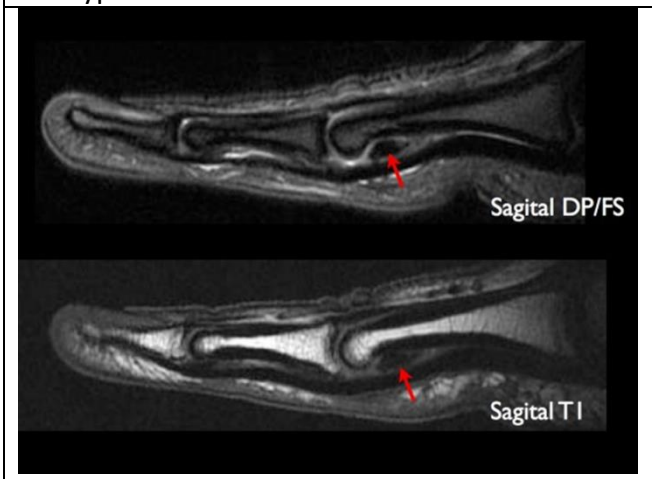
B- Volar Plate Injury

- Hyperextension of a finger joint, such as a dorsal dislocation, can injure the volar plate
- The volar plate forms the floor of PIP joint separating the joint space from the flexor tendon sheath.
- The volar plate has a ligamentous origin on the proximal phalanx with a capsular insertion onto the middle phalanx.

- A "jammed finger" is a common injury of the proximal interphalangeal (PIP) joint.
- It is an imprecise term, which subsumes a variety of injuries that are typically related to axial loading and hyperextension forces.

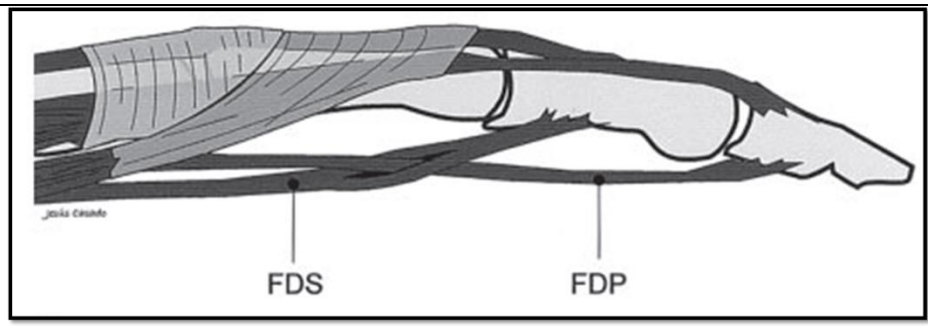
Classification of hyperextension injuries of PIP joint:

- Type I lesion = avulsion of the volar plate
- Type II lesion =avulsion of the volar plate with collateral ligament complex tear
- Type III lesion = fracture-dislocation of the volar base of the middle phalanx

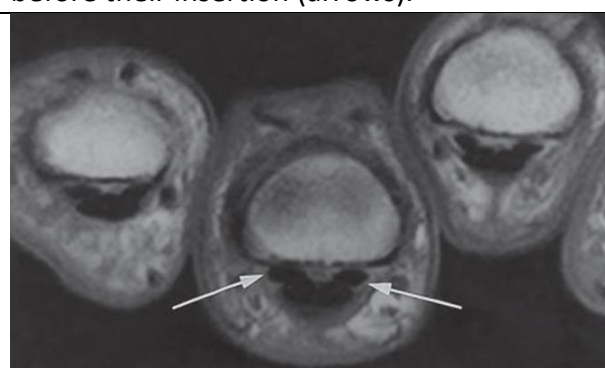


Type 3: Volar Plate Avulsion Fracture

FLEXOR Tendons



FDP: insertion on base of distal phalanx	FDS: insertion on the middle phalanx	Axial T1 obtained distal to the PIP joint shows the two slips of the FDS tendon immediately before their insertion (arrows).

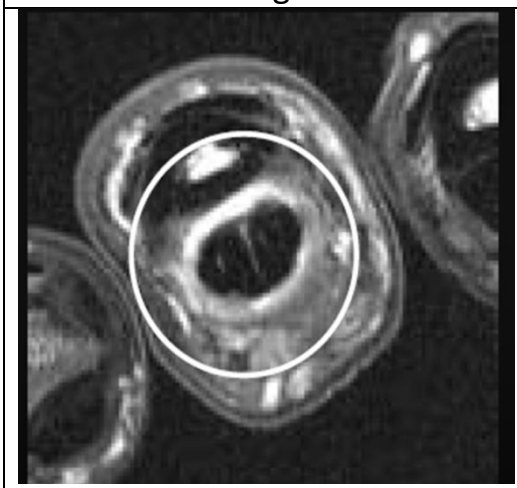


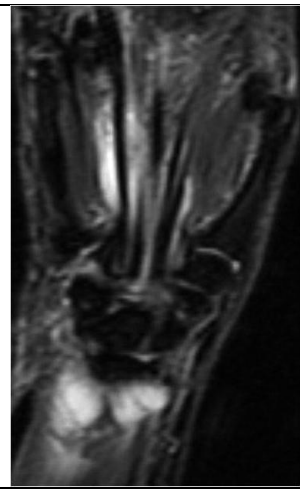
Trauma to the flexor tendons is divided into the following 5 zones:

Zone	Description
Zone I	Extends from the distal insertion of the FDP (volar aspect of the distal phalanx) to the distal insertion of the FDS insertion (volar aspect of the PIP and proximal middle phalanx)
Zone II	(Also referred to as "no man's land"); extends from the distal insertion of the FDS tendon to the distal palmer fold
Zone III	Extends from the proximal A1 pulley to the distal flexor retinaculum
Zone IV	Injury extending to the carpal tunnel
Zone V	Injury extending to the forearm

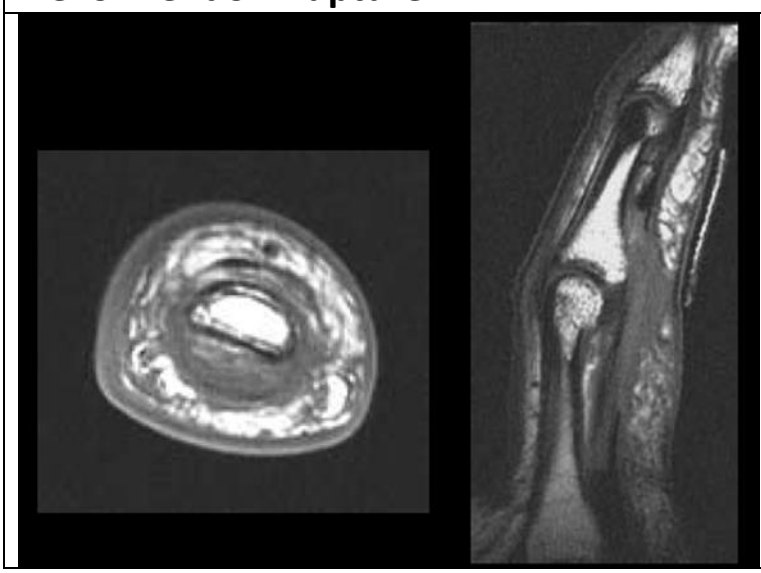
Flexor Tenosynovitis

Increased fluid signal within tendon sheath around intact tendon

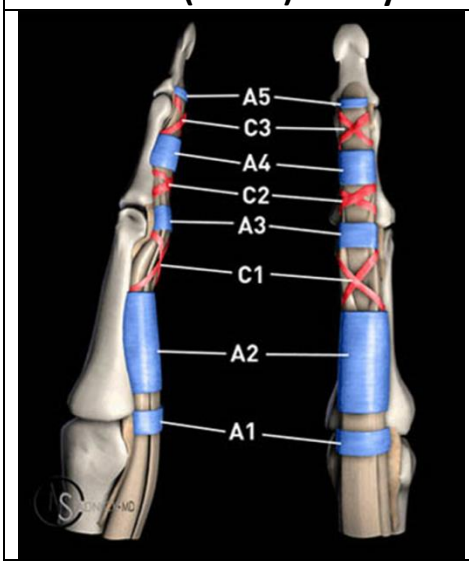
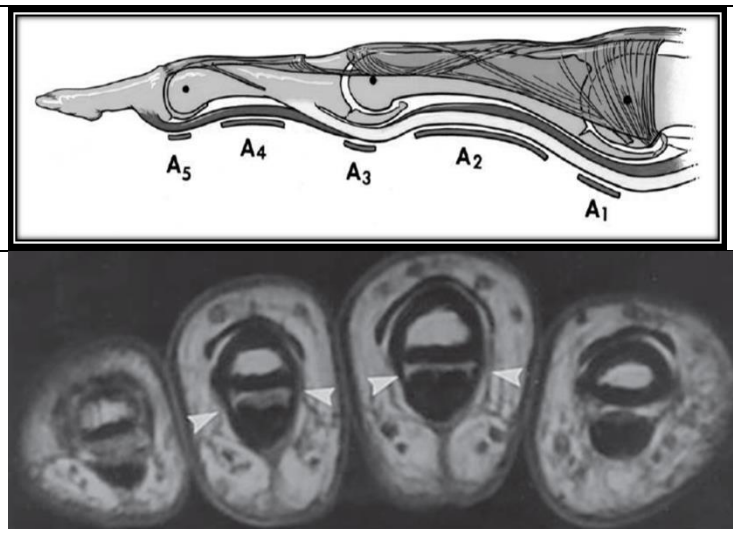




Flexor Tendon Rupture



Flexor Pulley System

5 Annular (A1-A5) Pulleys 3 Cruciate (C1-C3) Pulleys	
	

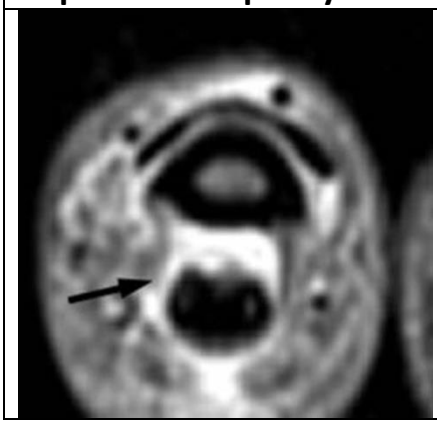
5 Annular Pulleys

- are transverse areas of fibrous thickening of the tendon sheath which help stabilize the flexor tendons and hold them flush against the volar aspect of the phalanges.
- These are labeled 1 though 5 and begin at the MCP joint (A1) extending to the distal interphalangeal (DIP) joint (A5).
- The 2 largest and most important pulleys are:
    - **A2 pulley located at the volar aspect of the mid-diaphysis of the proximal phalanx.**
    - **A4 pulley located at the volar aspect of the mid-diaphysis of the middle phalanx.**
- Rarely - A1 and A5 pulleys

❖ Complete Pulley Tears

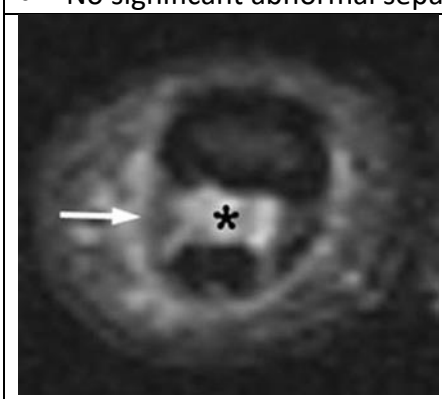
- "Bowstringing" = An abnormal gap between the flexor tendons and the adjacent phalanxes
- Fluid, edema, and widening between the flexor tendons and the proximal phalanx

Rupture of A2 pulley of the finger (Climber's Finger)



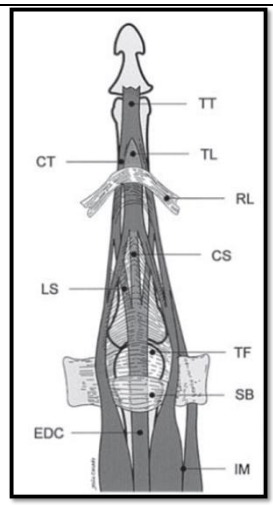
❖ Partial Pulley Tears

- oedema is seen along the course of the involved pulleys in the sagittal plane,
- Pulley edema or irregularity may be directly visualized on axial views.
- No significant abnormal separation of the tendons from the phalanxes is noted.



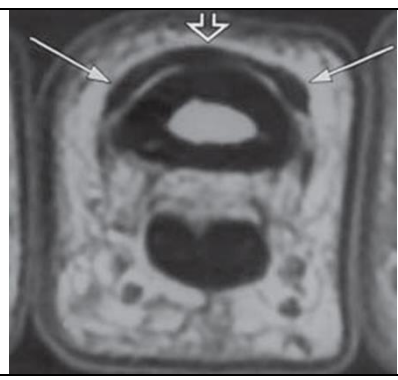
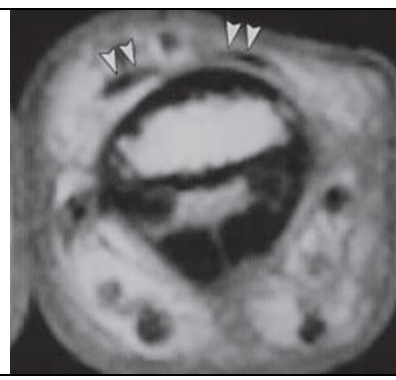
Extensor Tendons

Central slip (CS)
Conjoint tendon (CT)
Extensor digitorum communis tendon (EDC)
Intrinsic muscles (IM)
Lateral slip (LS)
Retinacular ligaments (RL)
Sagittal bands (SB)
Transverse fibers (TF)
Triangular ligament (TL)
Terminal tendon (TT).



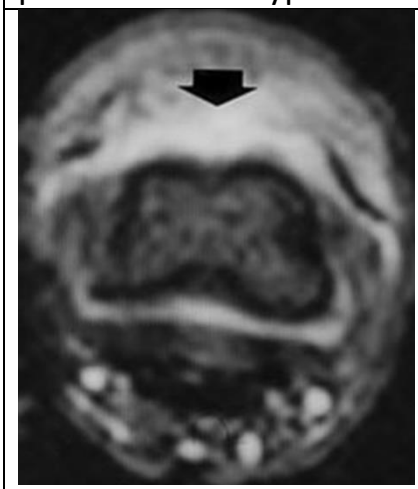
Insertion of the terminal tendon on the base of the distal phalanx (open arrow).

Insertion of the central slip on the base of the middle phalanx (solid arrow)

Axial at MCP joint	**Axial at PIP**	**Axial at middle phalanx**
Extensor digitorum communis tendon (open arrow) Sagittal bands (arrowheads) Interosseous tendon (straight solid arrow) Lumbrical tendon (curved arrow).	Central slip (open arrow) Lateral slips (solid arrows)	conjoint tendons (arrowheads)
		

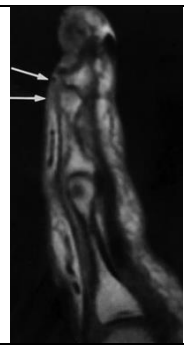
❖ Complete Laceration Of Central Slip

Complete laceration of the central slip at its insertion on the base of the middle phalanx with a hyperintense gap (arrows).



❖ Complete Laceration Of Conjoint Tendon

- Complete laceration of conjoint tendon at its distal insertion on base of distal phalanx. (arrows)
- Soft-tissue edema and hemorrhage.
- Flexion deformity of the distal phalanx



❖ Boutonnière Deformity

- Sagittal T1-weighted MR image shows
- Discontinuity of the central slip at its distal insertion on the base of the middle phalanx (long arrow).
- A classic deformity with flexion of the PIP joint and extension of the DIP joint is seen (short arrows).

Metacarpal Fracture

❖ Boxer's Fracture

- Mechanism of injury: punch with a closed fist
- Usually involves the 5TH metacarpal,
- but the 4th metacarpal may also be involved.

Phalangeal Fracture

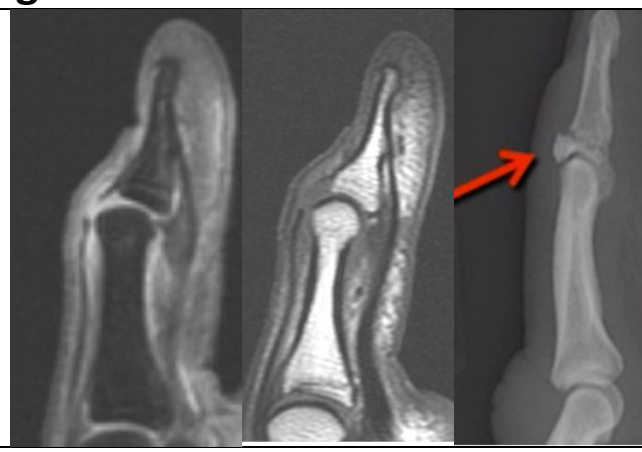
❖ Mallet Finger = Baseball Finger

Mechanism of Injury:

- Ball hits an extended finger

Pattern of Injury:

- ➢ Avulsion of the extensor tendon from the distal phalanx.
- ➢ &/or Fracture at the dorsal base of the distal phalanx.
- ➢ &/or Flexion deformity at DIP joint



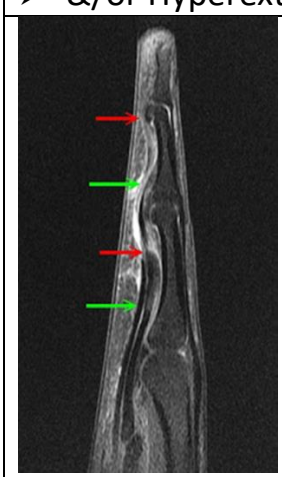
❖ Jersey Finger = Rugby Finger

Mechanism of Injury:

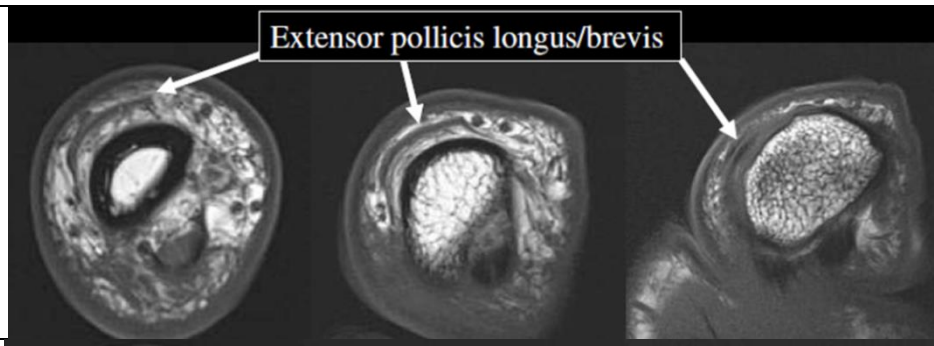
- A sudden hyperextension during active flexion

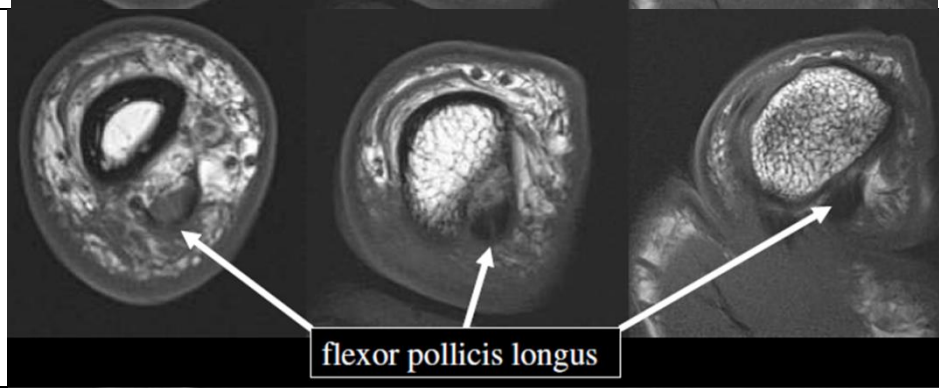
Pattern of Injury:

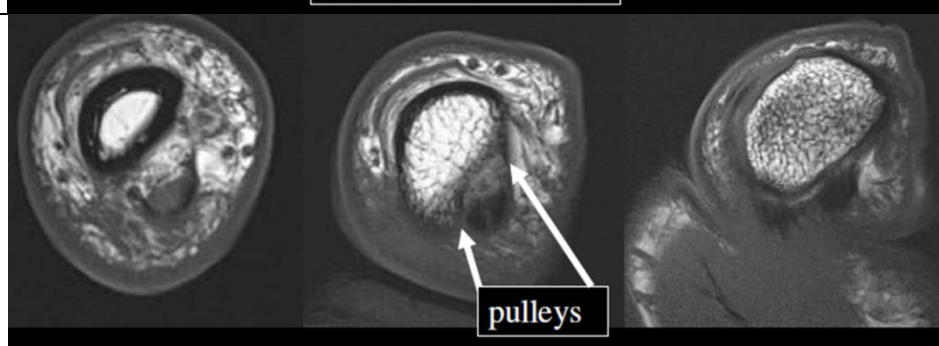
- ➢ Avulsion of the flexor digitorum profundus (FDP) at base of distal phalanx
- ➢ &/or Fracture at the volar base of the distal phalanx
- ➢ &/or Hyperextension deformity of DIP

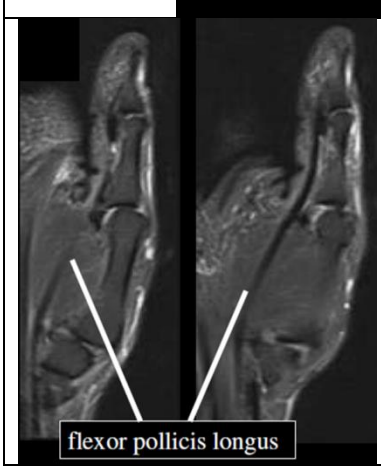


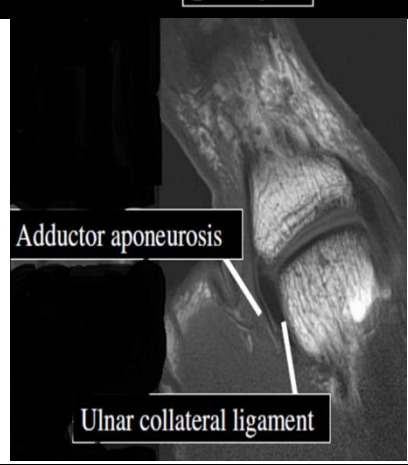
Thumb Injuries

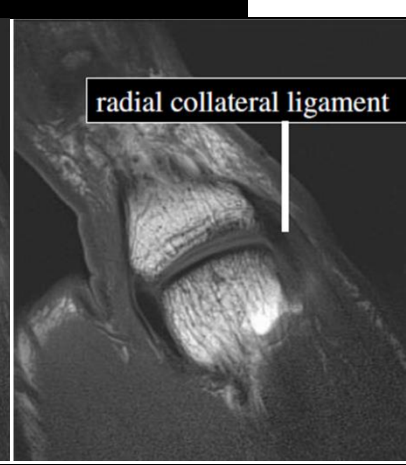












❖ Gamekeeper Thumb

Mechanism of injury:

Forced abduction of 1st MCP joint.

the injury is usually acute and seen in skiers caused by a similar stress on the first MCP joint from landing on the ground with their hand braced on a ski pole

Injury Patterns:

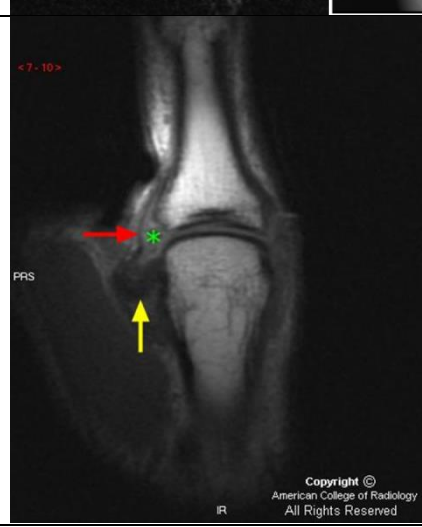
- Avulsion fracture at ulnar aspect of base of proximal phalanx of thumb.
- Ulnar collateral ligament injury (sprain or rupture).
- Avulsion fracture + Ligament injury.

Stener lesion

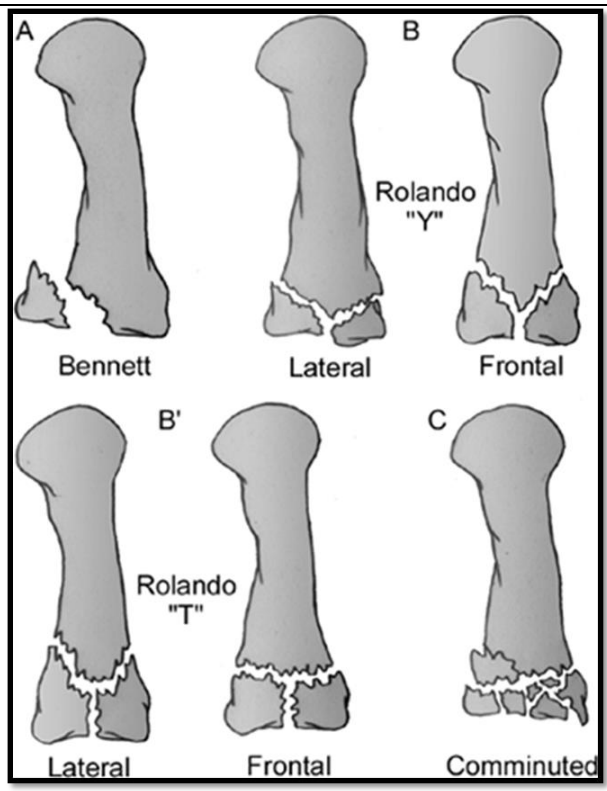
Complete tear of the UCL results in retraction proximally and superficial to the adductor aponeurosis, prevents spontaneous healing of the ligament

=> **Yo-yo on a string appearance**

Stener lesion is an indication for surgical intervention.



❖Fracture Base of 1st Metacarpal



Bennett Fracture

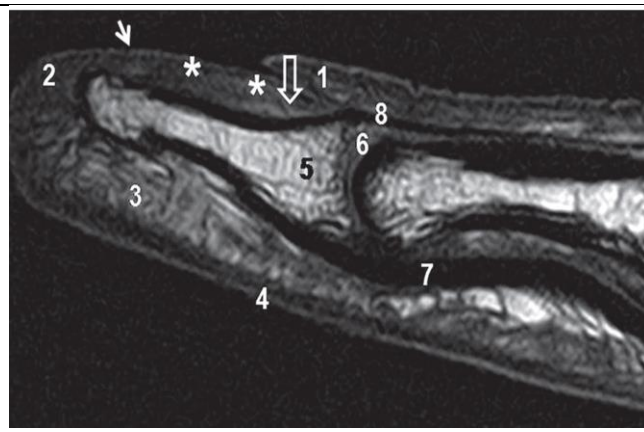
Rolando Fracture

Subungual Tumors

❖ Normal Anatomy:

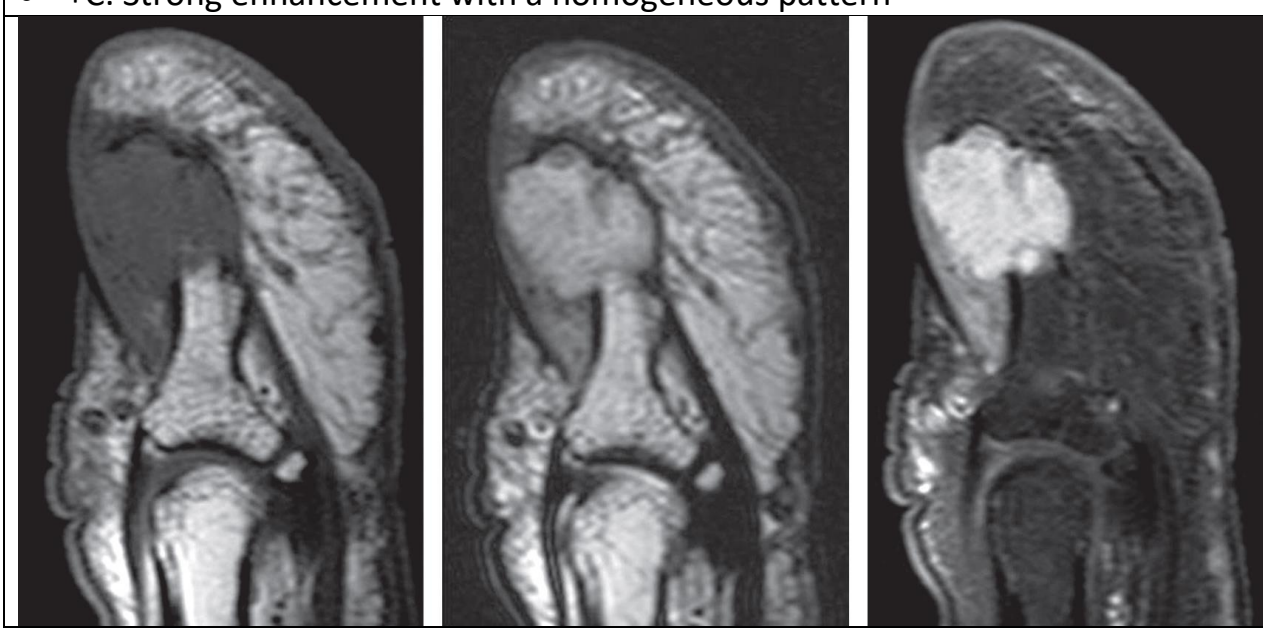
Sagittal T1

1) Proximal nail fold
2) Hyponychium
3) Pulp
4) Dermis and epidermis
5) Distal phalanx
6) Distal interphalangeal joint
7) Flexor digitorum profundus tendon
8) Terminal band of the extensor tendon
9) Submatrical hyperintense area (open arrow)
10) Nail plate (solid arrow)
11) Nail bed (*).



A) Glomus tumor

- Mass beneath the nail
- Erosion at the first distal phalangeal bone
- T1: Low signal
- T2: marked hyperintense signal
- +C: Strong enhancement with a homogeneous pattern

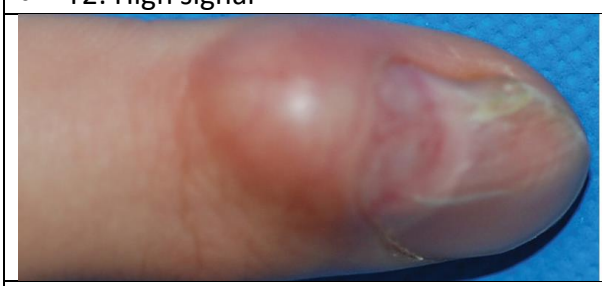


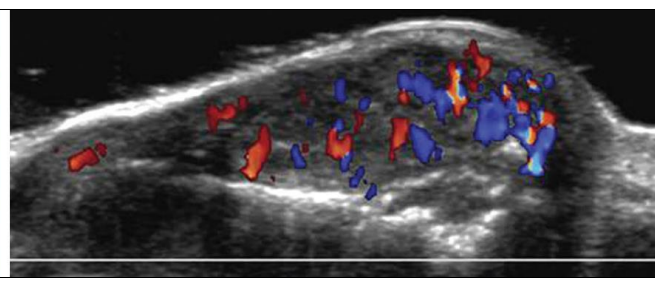
B) Subungual Exostosis = Dupuytren Exostosis

- Uncommon, solitary, benign bone lesion arising from the distal phalanx beneath the nail.
- Big toe most commonly affected.
- bony overgrowth, with a defined cortex, that projects from the dorsal or dorsomedial aspect of the distal phalanx
- The fibrocartilaginous cap in subungual exostosis is hypointense with all MR imaging sequences (whereas the hyaline cartilage in osteochondroma has high signal intensity on T2)

C) Soft-Tissue Chondroma

- Rare benign tumor that consists of a small nodule of cartilage without any connection to the underlying bone
- Calcification: hypointense foci in all MR imaging sequences
- T1: Low signal
- T2: High signal





D) Keratoacanthoma

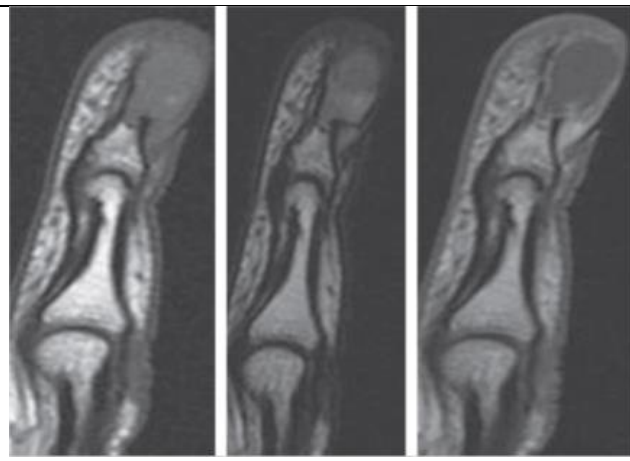
- Rare benign neoplasm that consists of localized proliferation of squamous epithelium with a characteristic central keratinfilled crater.
- Male predilection
- Age: 5th decade of life
- It may be locally destructive and is sometimes associated with malignant transformation to squamous cell carcinoma with subsequent invasion

E) Hemangioma

- T1: intermediate signal
- T2: extremely high signal
- Vascular components produce heterogeneous signal intensity with a serpentine pattern on T2-weighted images, along with flow void artifacts.
- Low signal intensity on T1- and T2- can be caused by phleboliths, calcifications, or fibrosis

F) Epidermal Cyst

- Although the exact pathogenesis of epidermal cysts remains controversial, it is believed that these lesions are caused by entrapment of epidermal fragments in other tissues of the digits by any type of injury, including trauma or an iatrogenic injury



Imaging findings:

- A well-defined cyst-like lesions
- Intermediate signal on T1- and T2-due to their heterogeneous histopathologic components, such as multiple layers of keratin debris
- +C: thin peripheral rim enhancement without central enhancement

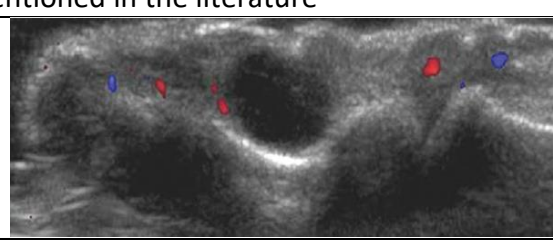
G) Mucoid Cyst

3 types:

- The most common type (80% of cases) is located in the distal interphalangeal joints; it is related to osteoarthritis and is characterized by a pedicle between the cyst and the distal interphalangeal joint.
- The second type has no connection with the distal interphalangeal joint. This cyst may develop independently from the underlying joint and result from local metaplasia, in which proliferation of fibroblasts produces an excess of hyaluronic acid.
- The third type is submatrical and is rarely mentioned in the literature

Imaging Findings:

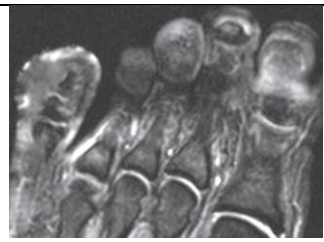
- A round or lobulated cystic masses
- T1: low signal
- T2: High signal
- +C: No enhancement.



H)Squamous Cell Carcinoma

Imaging Findings:

- T1: Low signal
- T2: High – intermediate signal
- +C: Heterogeneous enhancement.
- Underlying bone erosion, destruction, edema.



I) Malignant Melanoma

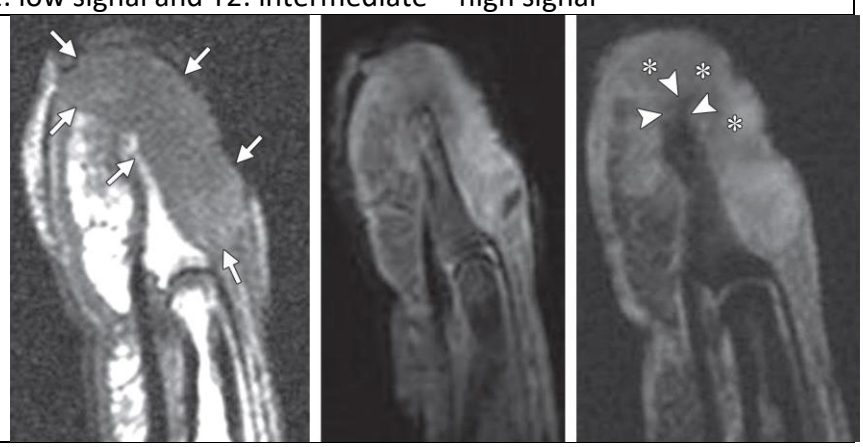
- Four distinct varieties of melanoma have been identified:
- Superficial spreading, nodular, lentigo maligna, and acral lentiginous melanoma
- Acral lentiginous melanoma occurring on palmar surface of hands and in subungual areas
- Common sites: thumb and big toe
- Age: middle-aged and elderly patients.

Clinical manifestations include

- Ingrown nail, simple split nail, junctional nevus, chronic paronychia with or without pain, and subungual pigmentation

MR imaging findings depend on amount of melanin and stage of intratumoral hemorrhage:

- Melanotic melanoma=T1: high signal and T2: Low signal
- Amelanotic melanoma = T1: low signal and T2: intermediate – high signal



Finger Osseous Tumors

1) Enchondroma

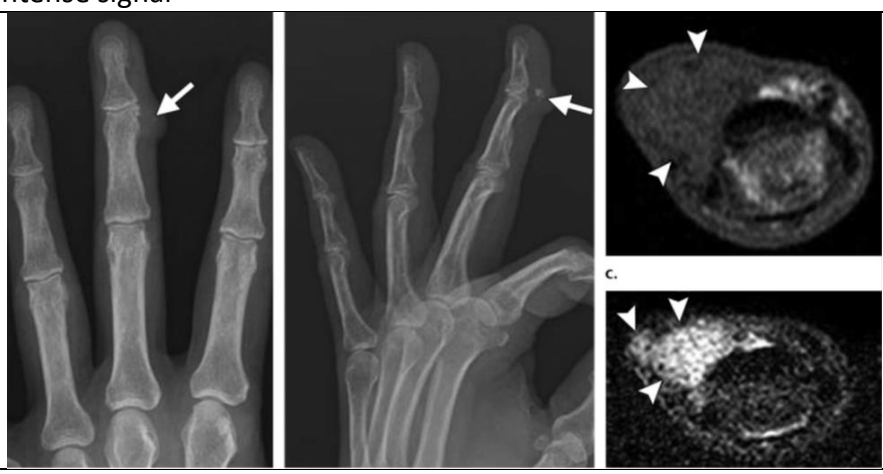
- Most common benign tumor of the hand.
- A well-marginated, mildly expansile lucent lesion
- Thinning and endosteal scalloping of cortex
- Predisposing to pathologic fracturing
- Chondroid matrix (arrows) with a stippled rings-and arcs appearance
- T2: hyperintense due to the high water content
- +C: peripheral nodular and septal enhancement

2) Multiple Enchondromatosis = Ollier disease

- rare nonhereditary disorder
- multiple expansile lucent lesions involving the metacarpal bones and proximal and middle phalanges

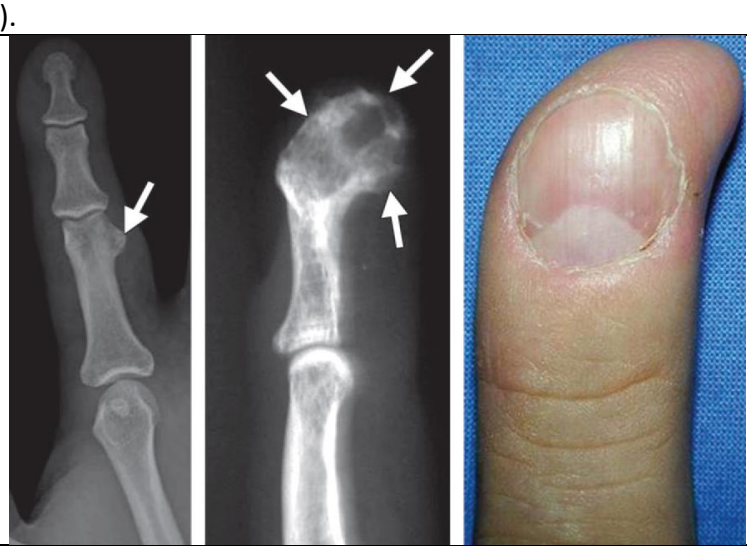
3) Periosteal / Juxtacortical Chondromas

- Uncommon
- Benign cartilagenous tumor
- Age: middle age < 30y
- Arise from periosteum surface of bones
- Radiolucent cortical based lesion + chondroid matrix
- Cortical saucerization / pressure erosions / scalloping
- Coarse calcification
- T1: Intermediate signal
- T2: Hyperintense signal



4) Osteochondroma

- Most common benign bone tumors
- Cortical and medullary bone with an overlying hyaline cap with continuity with the underlying parent bone cortex and medullary cavity.
- 2 distinctive radiographic appearances: sessile (broad based) and pedunculated (slender stalk or pedicle).



5) **Hereditary Multiple Exostoses**

6) **Bizarre Parosteal Osteochondromatous Proliferation (Nora Lesion)**

7) **Osteoid osteoma**

8) **Sarcoidosis**

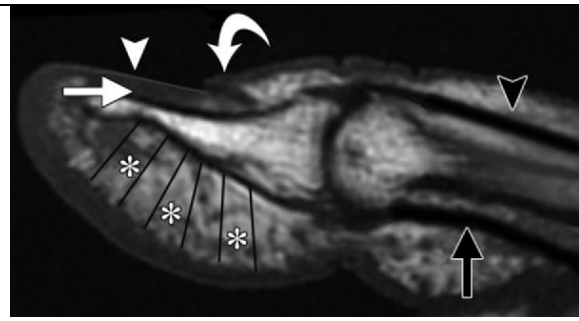
9) **Chondrosarcoma**

Hand Infections

❖ Anatomy

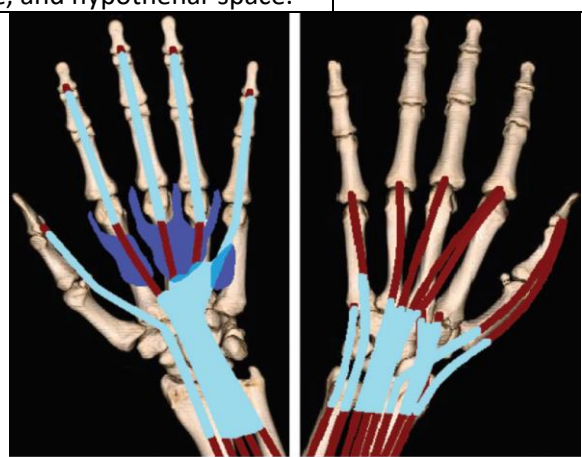
The nail complex anatomy:

- Nail plate [white arrowhead]
- Nail bed [straight white arrow]
- Eponychium [curved arrow])
- Pulp space (vertical trabeculations [black lines] and septal interstices [*])
- The extensor digitorum communis (black arrowhead)
- Flexor digitorum profundus (black arrow) tendon.



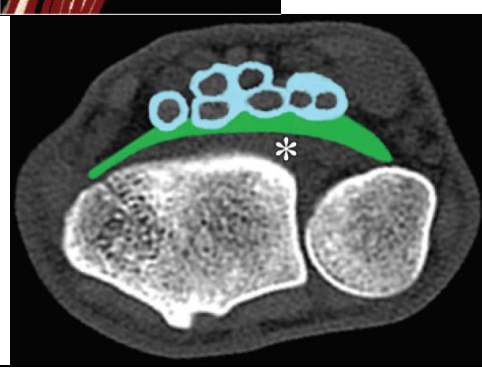
- Flexor tendons (brown)
- Flexor tendon sheaths
- Radial and ulnar bursae (light blue),
- Volar deep spaces (dark blue) include thenar space, midpalmar space, and hypothenar space.

Extensor tendons (brown)
Extensor tendon sheaths (blue).



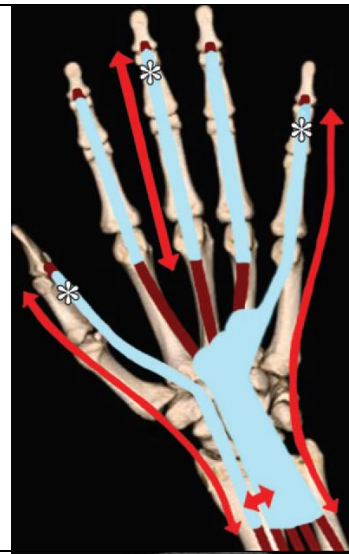
Space of Parona (green):

Potential space in the distal forearm between the fascia of the pronator quadratus muscle (*) and the flexor digitorum profundus tendon sheath (blue).

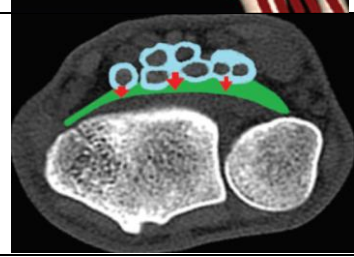


❖ Spread of infection

- Infection of the flexor tendon sheaths of the thumb and little finger
  - ⇨ Spreads to the radial and ulnar bursae, respectively (curved double-headed arrows).
- Infection of the tendon sheaths of the second, third, and fourth fingers
  - ⇨ Does not spread to the bursae unless there is direct communication (long straight double-headed arrow).
- Spread of infection between the radial and ulnar bursae (short straight double-headed arrow) which can occur through direct communication or through rupture into the space of Parona.



- Spread of infection of the space of Parona (green) can result from rupture of infection from the radial or ulnar bursa (blue).



Predisposing factors:

- Diabetes mellitus, intravenous drug use, alcohol consumption, steroids, gout, rheumatoid arthritis, peripheral vascular disease, and renal failure

Mode of Infections:

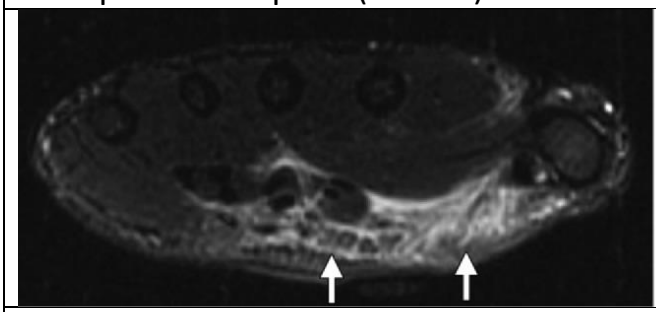
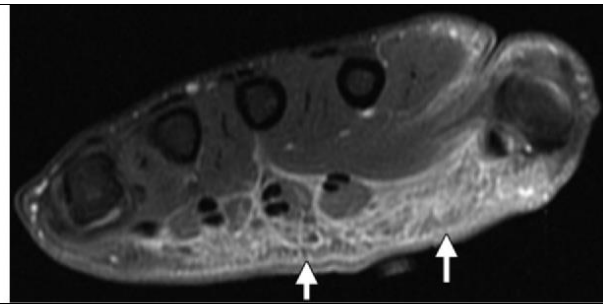
- Direct inoculation following penetrating injury (most common)
- Hematogenous infections are uncommon.

Types of Infection and Common Causative Organisms

Type of Infection	Common Causative Organisms
Cellulitis	*S aureus*, *Streptococcus* species
Necrotizing fasciitis	*Streptococcus* species, polymicrobes
Abscess (paronychia, felon, deep space infection)	*S aureus*
Flexor tenosynovitis	*S aureus*, anaerobes
Septic arthritis	*S aureus*
Human bite	*S aureus*, *Streptococcus* species, *Eikenella corrodens*, anaerobes
Animal bite	*Pasteurella multocida*, *S aureus*, *Streptococcus* species

A- Cellulitis

- Cellulitis is an infection of the subcutaneous tissues.
- Edema and enhancement without a focal fluid collection along the volar radial aspect of the palm (arrows).

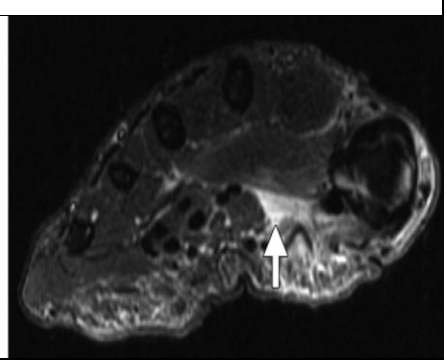



B-Paronychia

- is the most common hand infection
- It involves the soft-tissue fold around the fingernail and usually results from bacterial inoculation of the paronychial tissue caused by a sliver of nail or a hangnail, a manicure instrument, or nail biting.
- Infections can spread:
    - Volarly into the pulp space
    - Along the eponychium to the opposite side of the nail, resulting in “runaround infection.”
    - Distal phalanx, resulting in osteomyelitis

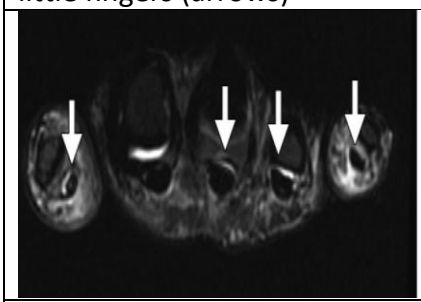
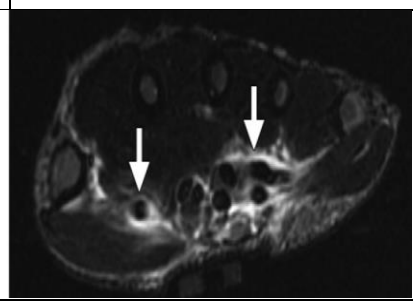
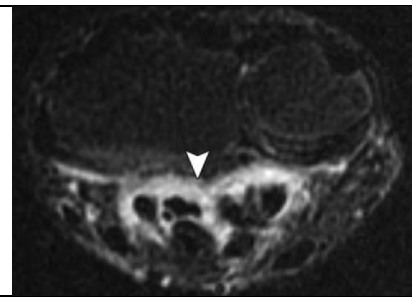
C-Pulp Space Infection (Felon)

- Infection of the distal pulp of the finger or thumb
- Infection can extend
    - Superficially to the skin => Necrosis and sinus tract formation.
    - Deep toward the phalanx => Osteomyelitis
    - Septic arthritis of the distal interphalangeal joint
    - Pyogenic flexor tenosynovitis



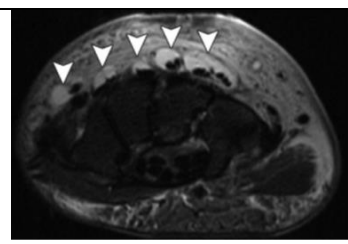
D- Pyogenic Flexor Tenosynovitis

- Closed-space infection of the flexor tendon sheath.
- Increased pressure within the tendon sheath leading to tendon necrosis and rupture
- Formation of adhesions can lead to severe restriction of motion.

Edema, fluid and enhancement extending along the flexor tendon sheaths of the thumb, middle, ring, and little fingers (arrows)	Edema, fluid and enhancement extending along the radial and ulnar bursae (arrows)	Edema, fluid and enhancement extending into the space of Parona (arrowhead
		

E- Extensor Tenosynovitis

- Closed-space infection of the extensor tendon sheath.
- Edema, fluid and enhancement extending along the extensor tendon sheaths of the index, middle, ring, and little fingers (arrowheads)



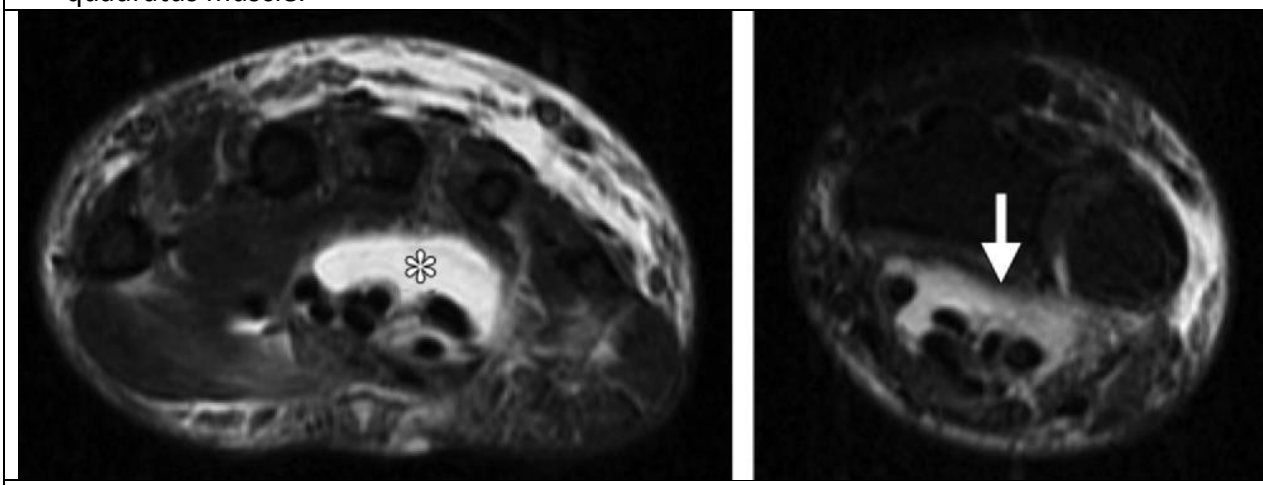
F- Thenar Space Infection

- This infection may occur as a result of:
  - Penetrating injury;
  - Local spread from flexor tendon sheath infection of thumb, index, middle finger
  - Extension from a subcutaneous infection.

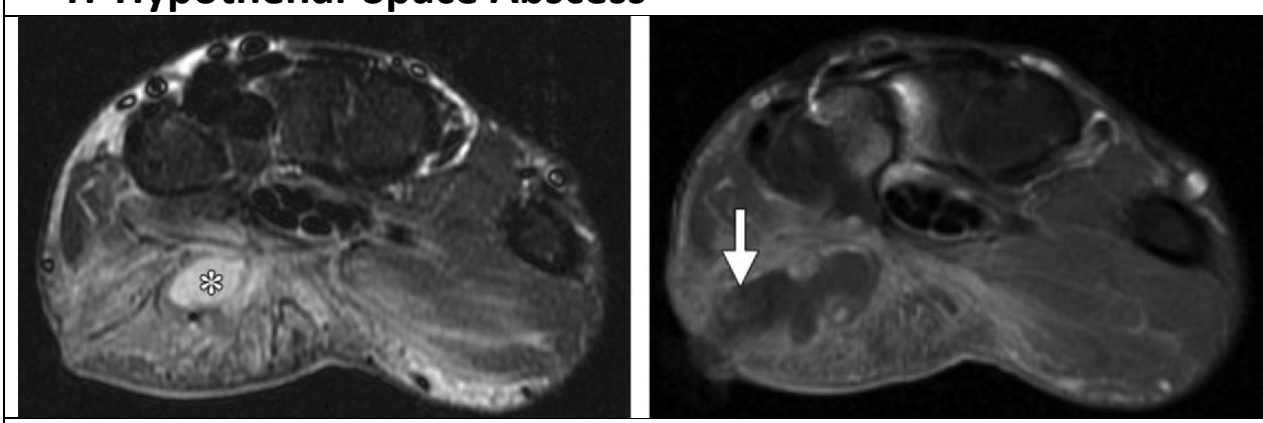
- Thenar space infection usually spreads dorsally over the adductor pollicis and first dorsal interosseous muscles, resulting in a dumbbell-shaped abscess that protrudes subcutaneously over the dorsal and radial aspect of the hand.

G-Midpalmar Space Infection

- Fluid in the deep palmar space (*) communicating with the space of Parona (arrow).
- The fluid in the space of Parona is deep to the flexor tendons and volar to the pronator quadratus muscle.

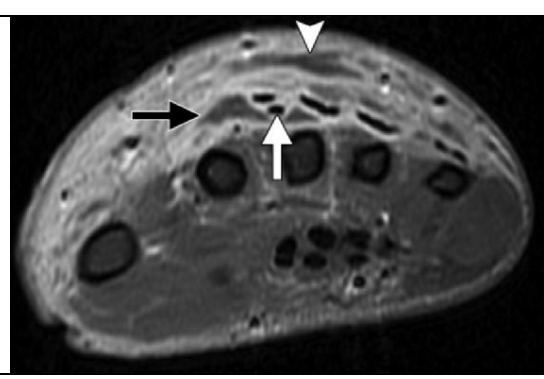


H-Hypothenar Space Abscess



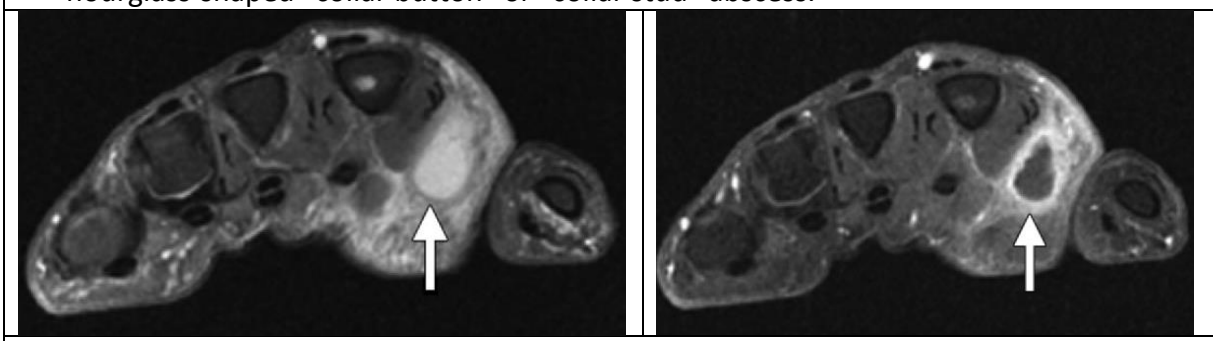
I- Infection of dorsal subcutaneous space and dorsal subaponeurotic space

- Extensive dorsal cellulitis with pockets of fluid in the dorsal subcutaneous (arrowhead) and subaponeurotic (black arrow) spaces, located superficial and deep to the extensor tendons
- infection of the dorsal subcutaneous space easily extends into the subcutaneous tissues of the forearm, since there is no barrier to the spread of infection



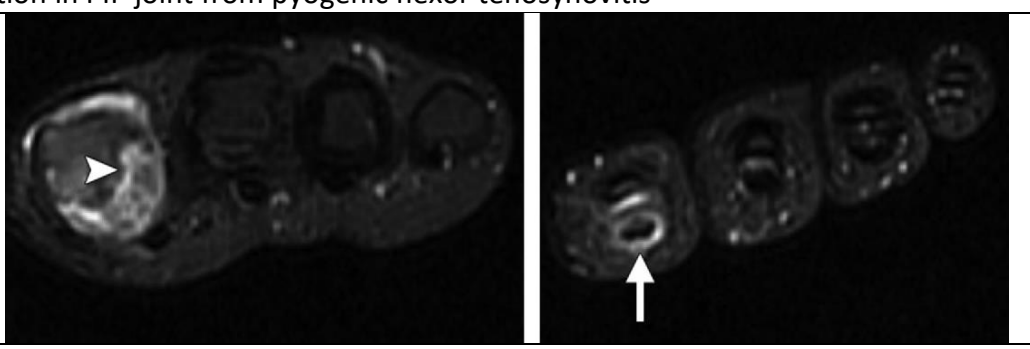
J- Infection Of Web Space

- The strong attachment of the palmar fascia to the skin limits volar extension.
- so that the infection tracks dorsally along the path of least resistance
- Pus in the interdigital web space can extend both volarly and dorsally, resulting in an hourglass-shaped “collar button” or “collar stud” abscess.



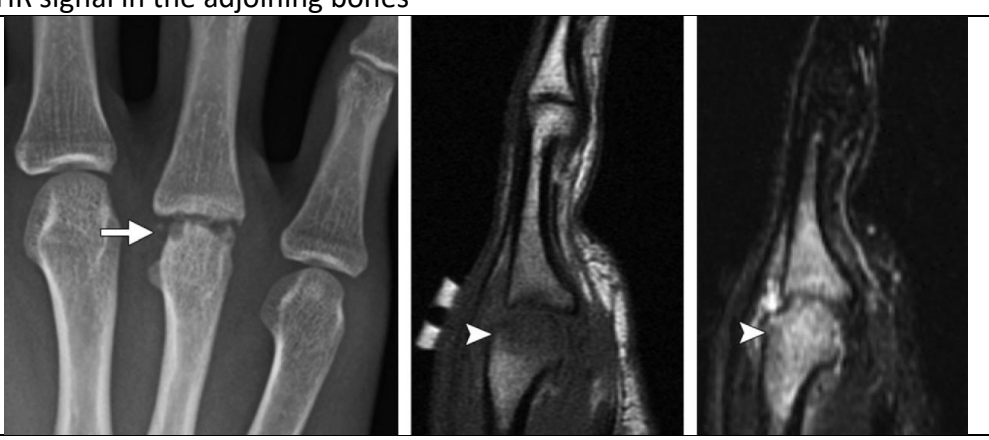
K- Septic Arthritis

- usually occurs secondary to penetrating injury.
- Infection in DIP joint from felon, paronychia, or pyogenic flexor tenosynovitis.
- Infection in PIP joint from pyogenic flexor tenosynovitis



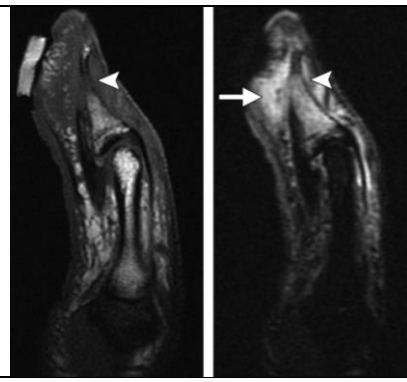
L- Fight bite

- MCP joints are usually inoculated directly from a clenched-fist injury (“fight bite”)
- Fluid signal distending the joint capsule
- High STIR signal in the adjoining bones



M- Acute Osteomyelitis

- most commonly results from penetrating injury,
- contiguous spread from adjacent soft-tissue infection or septic arthritis surgery, and hematogenous spread

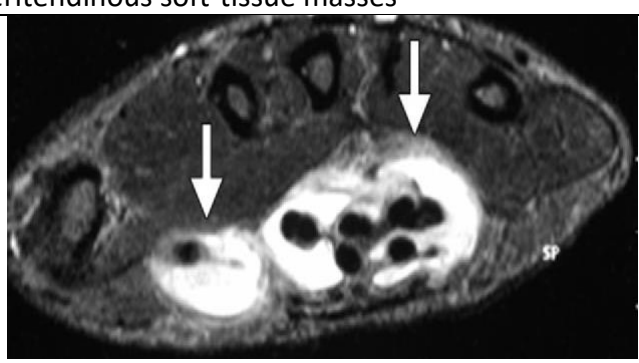


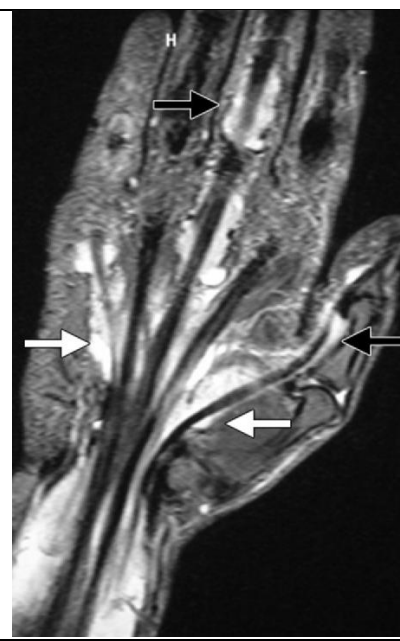
N- Chronic Osteomyelitis

- Periosteal new bone formation and sclerosis (arrows).

O- Tuberculosis

- Most common cause of chronic hand infection
- Extensive synovitis and distention of the tendon sheaths (black arrows) and the radial and ulnar bursae (white arrows)
- Thickening of the synovium with low-signal material in the synovial fluid, with tendon involvement
- Peritendinous soft-tissue masses





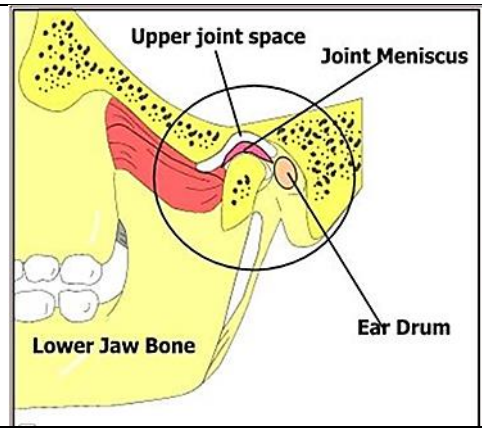
Temporomandibular Joint

❖ Anatomy

- A true synovial joint capable of gliding, hinging, sliding and slight rotation

TMJ complex

- Condyle of mandible
- Mandibular fossa
- Articular tubercle of the temporal bone
- Articular disk (meniscus)

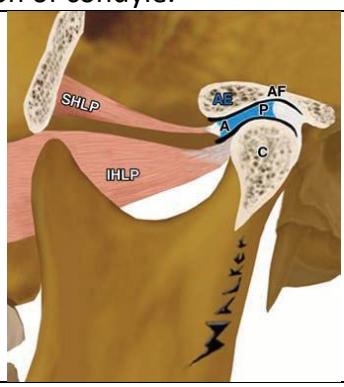
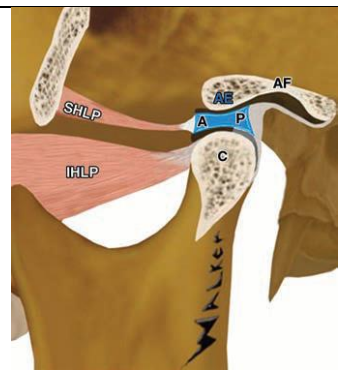


❖ MRI Imaging Technique

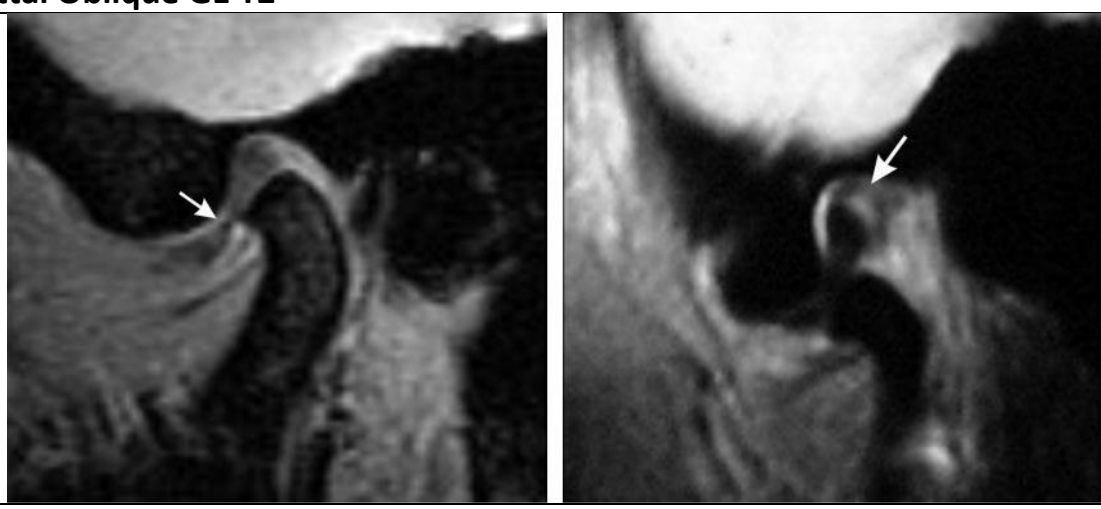
Plane	Sequence	Slice thickness	TR	TE	Mouth open/closed
Axial	T1	2 mm, 0 skip	500	Minimal	Closed
Coronal	T1	3 mm, 0.5 skip	500	Minimal	Closed
Bilateral Sag Oblq	T2 and PD	3 mm	3500	Min and 85	Closed and open
Bilateral Sag Oblq	T2	3 mm	1180-2000	64	Dynamic cine

❖ Normal Articular Disk / Meniscus:

- A biconcave fibrocartilaginous structure
- Divides this synovial joint into superior and inferior compartments
- Its function is to accommodate a hinging action & the gliding action that occurs between the temporal bone and the mandible.
- Thick anterior band + Thick posterior band + Thin center (intermediate zone)
- Sagittal MRI: biconcave structure with homogeneous low signal intensity
- The disc attached posteriorly to bilaminar zone, which demonstrates intermediate signal.
- The disc is attached anteriorly to lateral pterygoid muscle (LPM)

Closed Mouth View	Open Mouth View
• Mandibular condyle (C) articulating with articular fossa (AF). • Thick posterior band of the meniscus lies immediately above the condyle. • Posterior band (P) is at 11–12 o'clock position of condyle.	• Mandibular condyle (C) articulates with articular eminence (AE). • The thinner intermediate zone of the meniscus becomes the articulating surface between condyle and articular eminence.
	

Sagittal Oblique GE T2



❖ Normal Retro-diskal Tissue

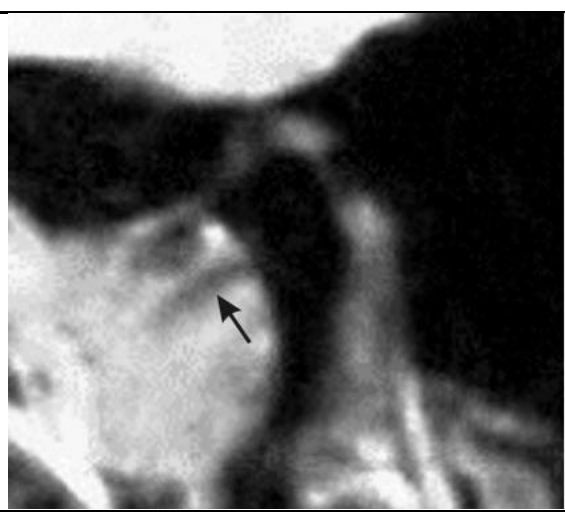
- The disc attached posteriorly to the bilaminar zone, which demonstrates intermediate signal intensity.
- The posterior band and retrodiskal tissue are best depicted in the open-mouth.
- These structures play an important role in normal disk movement
- Superior retrodiskal layer (arrow) between the posterior band and the mandibular fossa

Sagittal T2 GRE	Sagittal PD SE

❖ Normal Lateral Pterygoid Muscle (LPM)

- Attachment of the inferior LPM (arrow) just below the disk

Closed-mouth position	Open-mouth position
Thin insertional area of the inferior LPM (arrow).	The insertional area of the inferior LPM (arrow) has increased due to contraction of muscle



Internal Derangement

- Abnormal relationship of the disk to the condyle.

Clinical Features

- Clicking sounds from joint(s)
- Restricted or normal mouth opening capacity
- Deviation on opening
- Pain

Imaging Features

- Abnormal disk displacement
- Abnormal disk morphologic features
- joint effusion

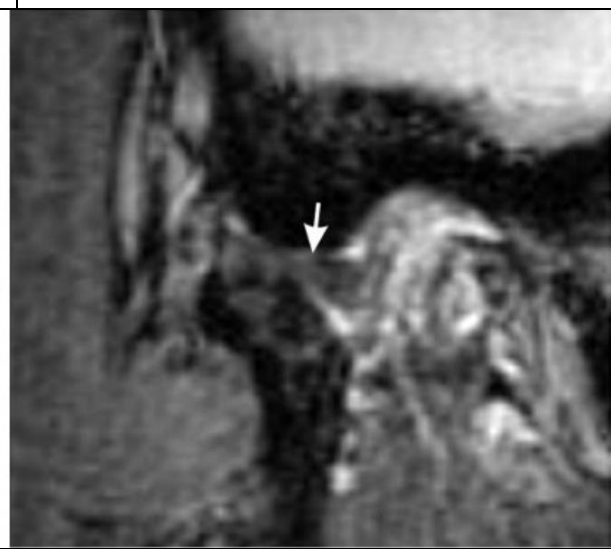
Indirect MR imaging signs of dysfunction

- Rupture of retrodiskal layers
- Thickening of an LPM attachment

1) Abnormal Disk Displacement

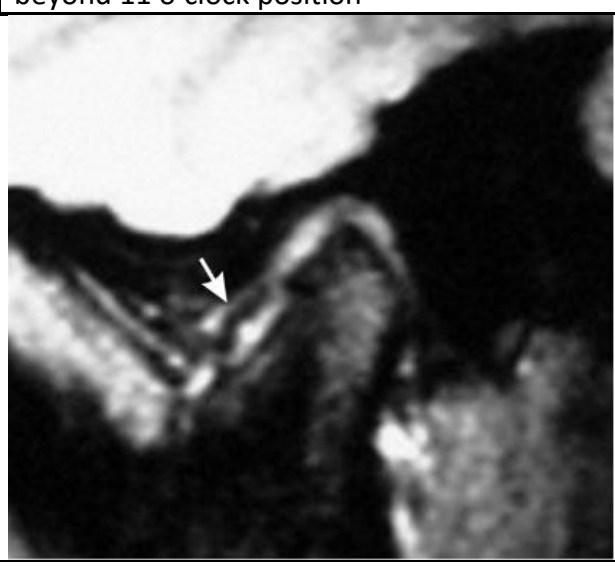
i) Anterior disk displacement with reduction:

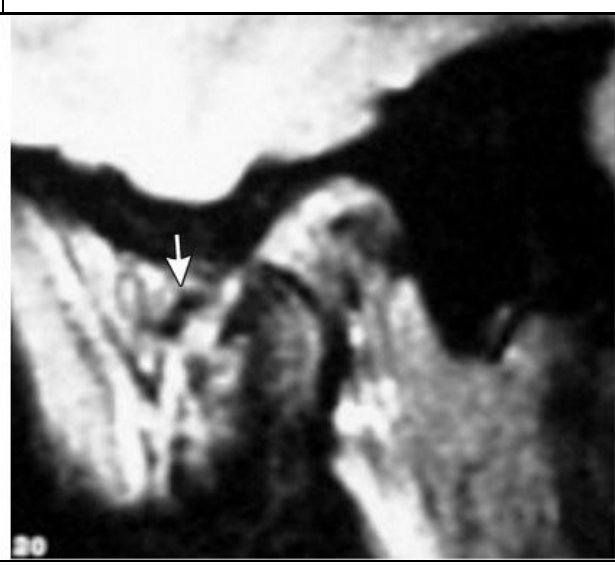
Closed mouth view.	Open mouth view
The disc is displaced anteriorly >10^{o} from vertical beyond 11 o'clock position	**The disc returns to its normal position**



ii) Anterior disk displacement without reduction:

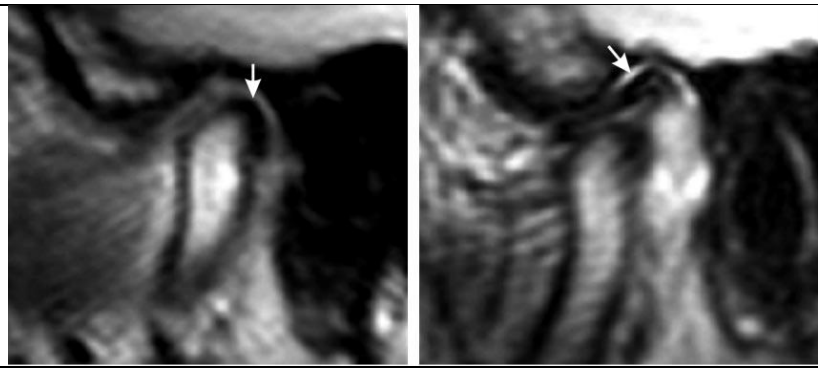
Closed mouth view	Open mouth view
The disc is displaced anteriorly >10^{o} from vertical beyond 11 o'clock position	The disc remains displaced anteriorly





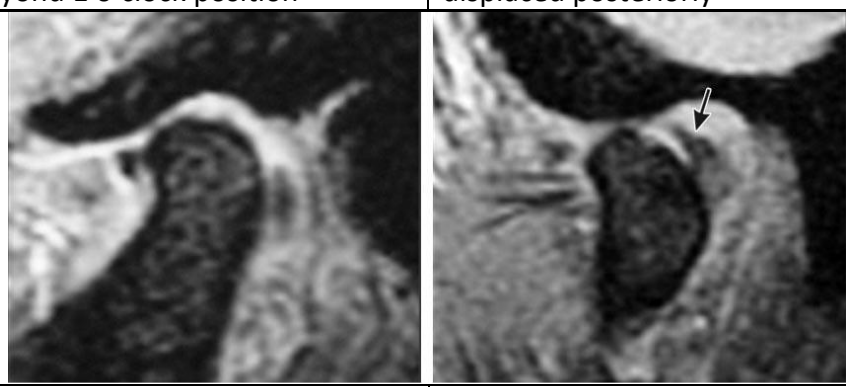
iii) Stuck Disk

- The disk remains in a fixed position relative to the glenoid fossa and the articular eminence in both closed- and open-mouth positions
- Probably due to the formation of adhesions.
- Causes limitation of condylar translation and may be associated with pain and joint dysfunction



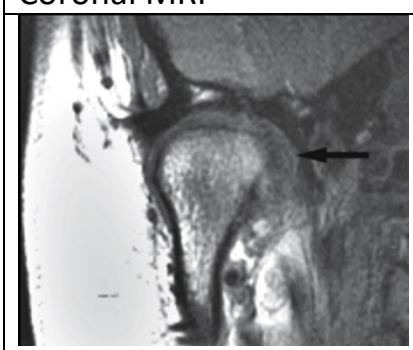
iv) Posterior Disk Displacement

Closed mouth view	Open mouth view
The posterior band of the disc is displaced posteriorly beyond 1 o'clock position	The posterior band of the disc remains displaced posteriorly



v) Medial disc displacement

Coronal MRI

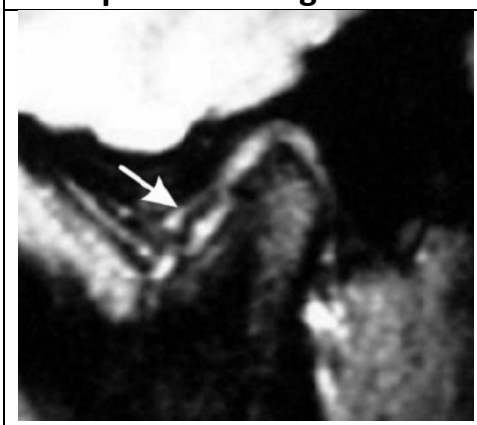


vi) Lateral disc displacement

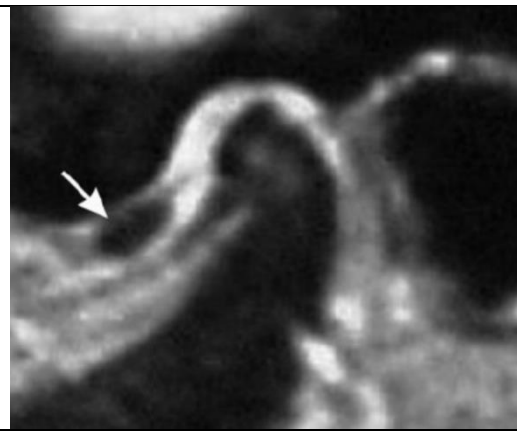
2) Abnormal Disk Morphologic Features:

- A displaced disk that has lost its typical biconcavity:

Crumpled and irregular



Rounded

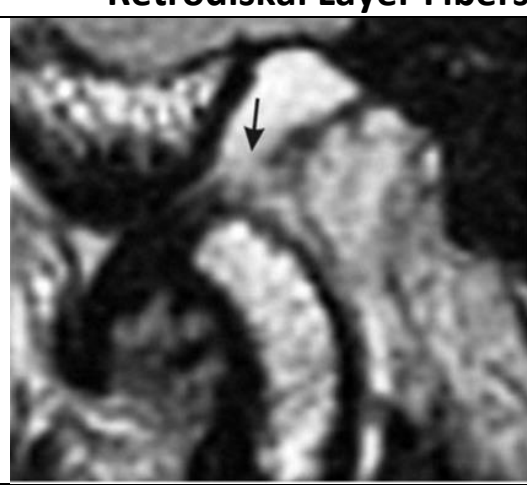


Flattened

Perforation of intermediate zone

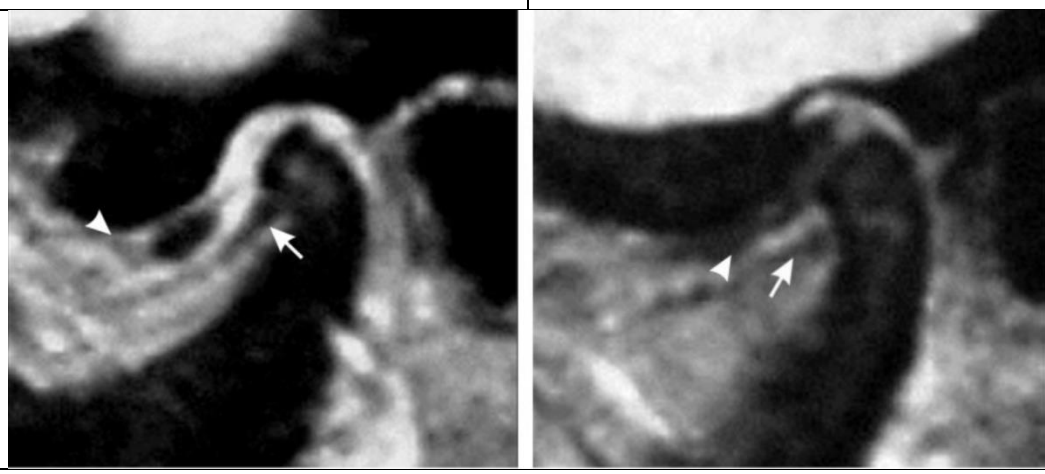
3) Joint Effusion

4) Rupture of Superior Retrodiskal Layer Fibers

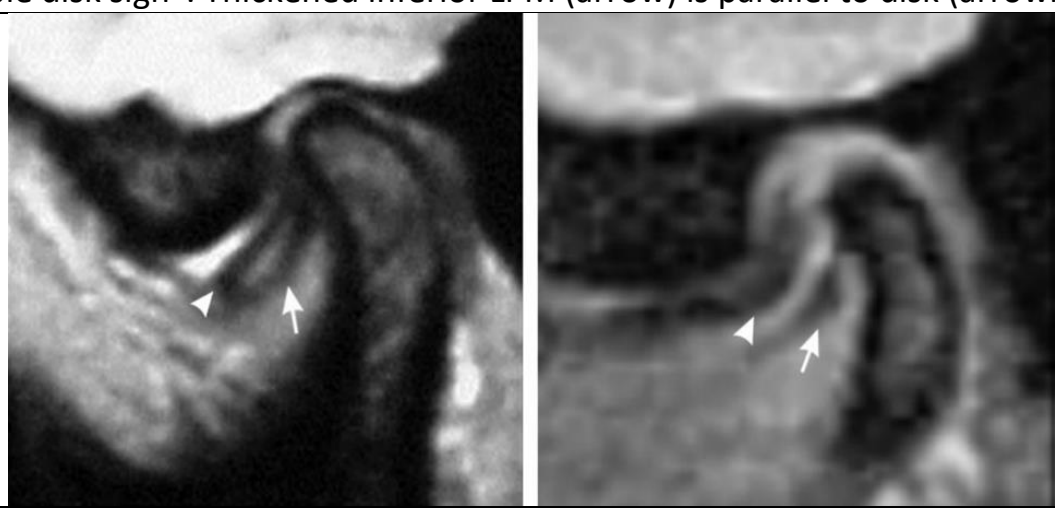


5) Abnormal LPM Attachment

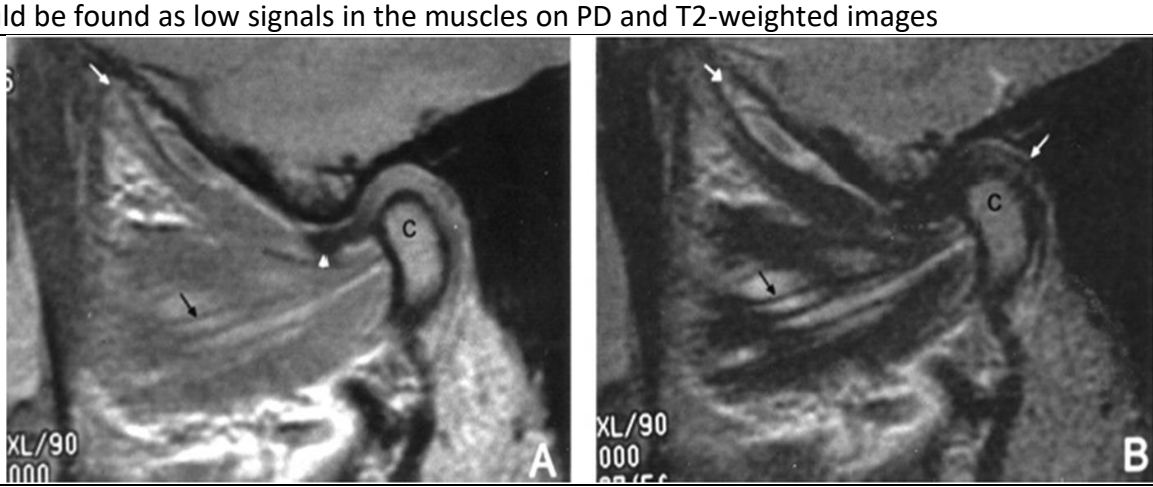
Abnormal thickened inferior LPM	Normal Inferior LPM



"Double disk sign": Thickened inferior LPM (arrow) is parallel to disk (arrowhead)



Contracture of the LPM presented as size of the muscles increased, at the same time fibrosis could be found as low signals in the muscles on PD and T2-weighted images



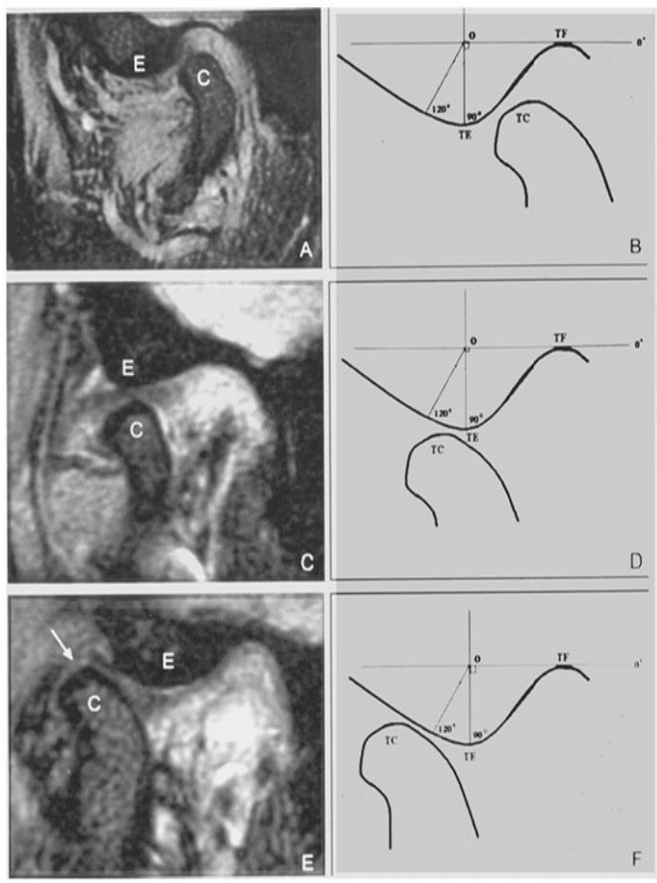
❖Classifications Of Condylar Mobility

A horizontal tangential line of the top of the articular fossa and a vertical line through the top of articular eminence are made on sagittal or oblique sagittal image of TMJ.
Two lines meet in point “O”. From the point “O”, making angles divide the articular eminence.
The top of the articular fossa (TF) is on 0º and the top of the articular eminence (TE) on 90º. (C = condyle, E = articular eminence, TC = top of the condyle).

<u>Hypomobility (limitation) of the condyle</u> shows in maximal mouth open imaging.
Hypomobility of the condyle shows as the top of the condyle locates < 90º.

<u>Normal mobility of the condyle</u> shows in maximal mouth-open imaging.
Normal motion shows as the top of the condyle located in 90º-120º of the eminence in maximal mouth opening

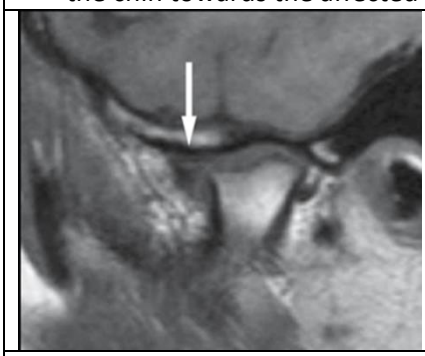
<u>Hypermobility of the condyle</u>
Note that the hypermobilized condyle may put pressure on the anterior part of the disc (arrow).
The condyle translates excessively, beyond and superior to the level of the articular eminence (> 120º) in the images of mouth maximal opening.



Congenital / Developmental Abnormalities

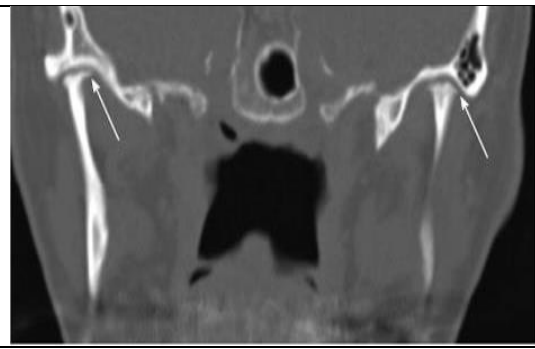
❖ Condylar Hypoplasia

- Condylar hypoplasia may be congenital
- But is usually the result of trauma or infection.
- The most common facial deformity is shortness of the mandible with deviation of the chin towards the affected side.



❖ Idiopathic condylar resorption

- Idiopathic condylar resorption (also known as condylysis or “cheerleader syndrome”) is primarily a disease of TMJ affecting teenage girls.



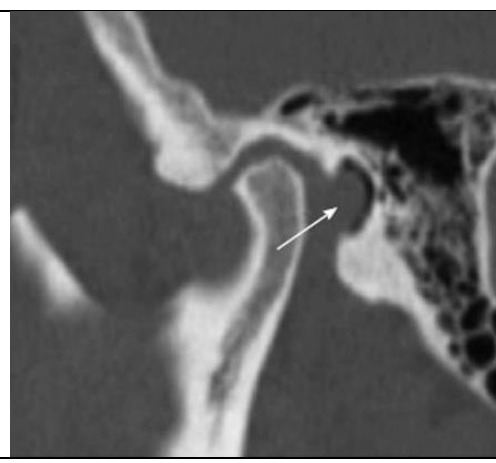
❖ Bifid Condyle

❖ Condylar Hyperplasia

- rare disorder characterized by increased volume of mandibular condyle, and is frequently associated with increased volume of ramus and mandibular bod

❖ Extensive Pneumatization

❖ Foramen of Huschke



TMJ Arthritis

❖Osteoarthritis of TMJ

- Non-inflammatory focal degenerative disorder of synovial joints, primarily affecting articular cartilage and sub-condylar bone; initiated by deterioration of articular soft-tissue cover and exposure of bone.

Clinical Features

- Crepitation sounds from joint(s)
- Restricted or normal mouth opening capacity
- Pain or no pain from joint areas and/or of mastication muscles
- Occasionally, joints may show inflammatory signs
- Women more frequent than men

Imaging Findings:

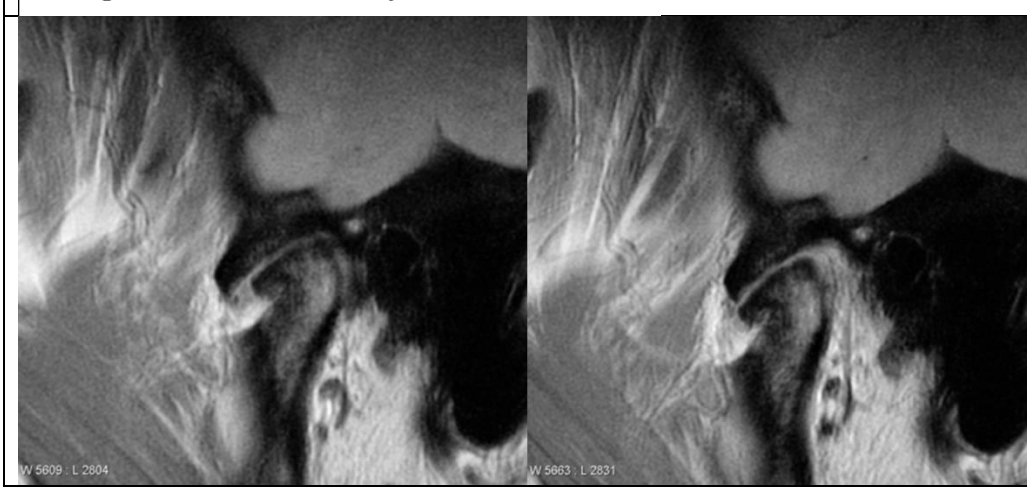
- **Flattening**
- **Osteophytes**
- **Erosions**
- **Sclerosis**

Indirect signs

Large amount of joint fluid (joint effusion)

Increased thickness of LPM attachments

Rupture of retrodiskal layers

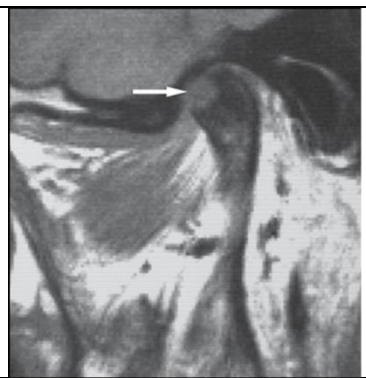
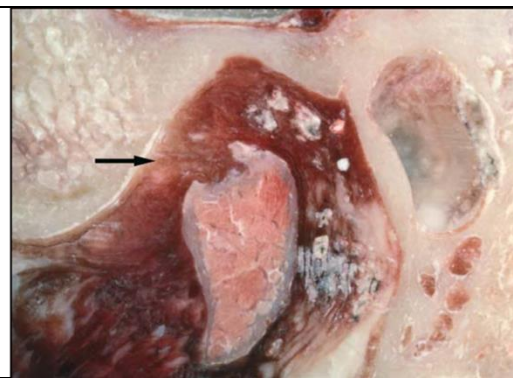
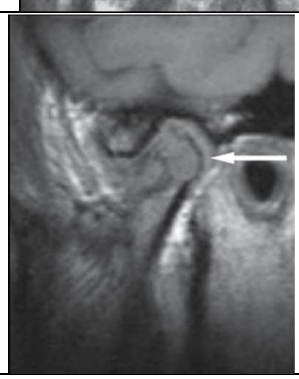
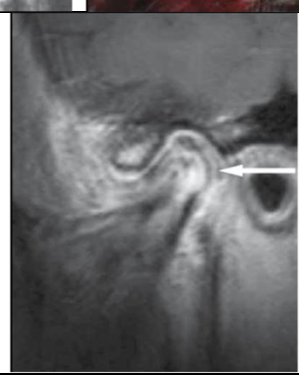
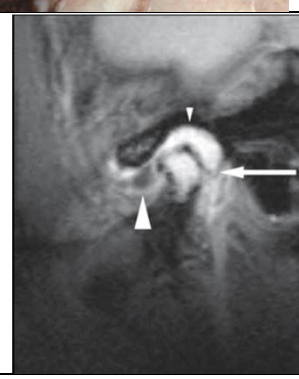


❖Inflammatory Arthritis

- Inflammation of synovial membrane characterized by edema, cellular accumulation, and synovial proliferation (villous formation).

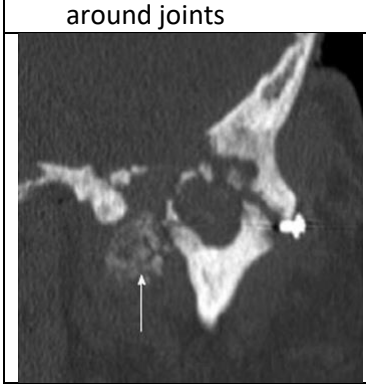
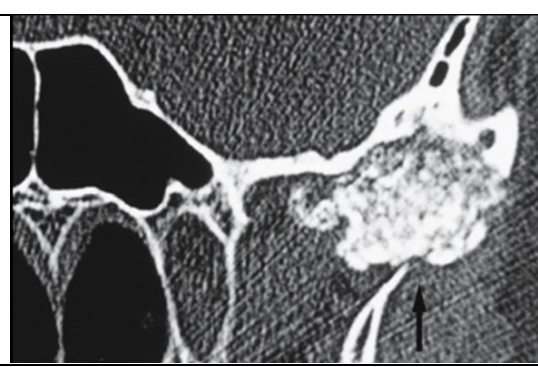
Imaging Features

- Cortical punched-out erosions
- Abnormal disc (flattened, elongated)
- Disc fragments, or completely destroyed disc may be found
- Active disease:
  - Marrow edema and/or joint effusion
  - Enhancement of synovial membrane, pannus
- Fibro-osseous ankylosis may be 'end-stage' of inflammatory disease
- Secondary osteoarthritis

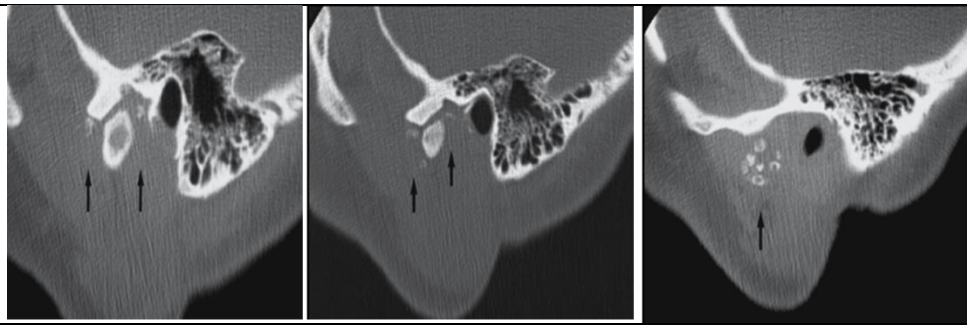
❖Metabolic Arthritis/Crystalline Arthropathies

- Metabolic arthropathy caused by the deposition of calcium pyrophosphate dehydrate crystals in and around joints

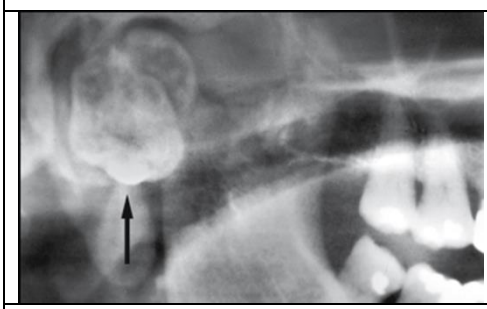



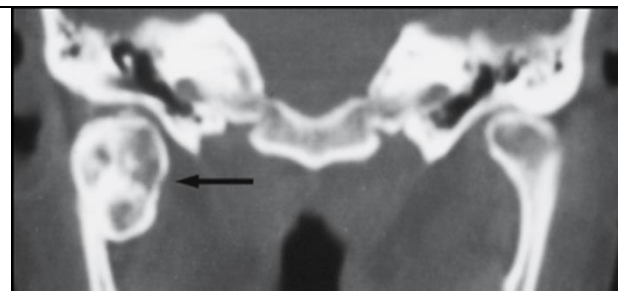
TUMORS AND TUMOR-LIKE CONDITIONS OF TMJ

❖Synovial Chondromatosis

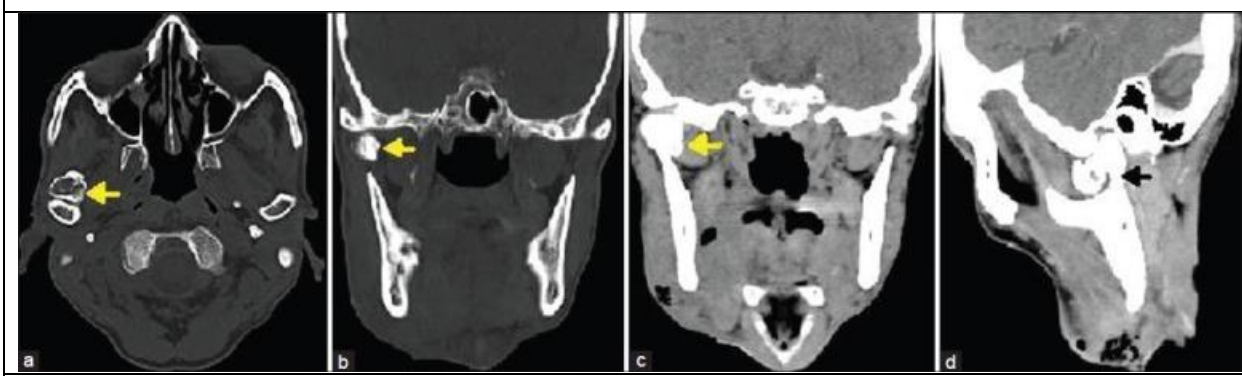


❖Osteoma

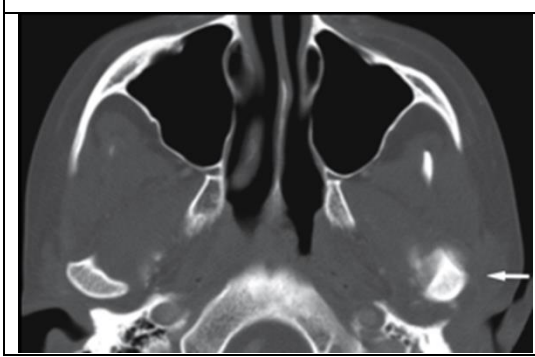




❖Osteochondroma



❖Osteosarcoma

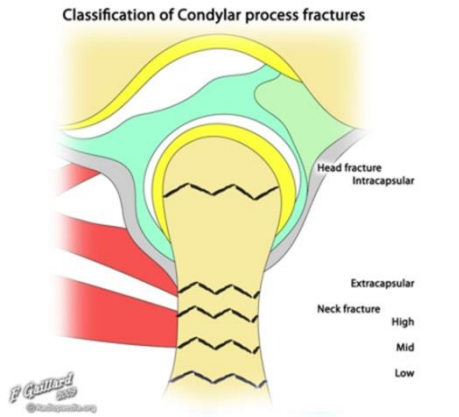


Condylar Process Fractures

30% of mandibular fractures.

Classification

- Head
  - Intracapsular
  - Extracapsular (similar to high neck fracture)
- Neck
  - High (similar to extracapsular head fracture)
  - Mid
  - Low



TMJ Dislocation

Sacroiliac Joint

(See Seronegative Arthritis)

The sacroiliac (SI) joint is a synovial and fibrous joint between ilium and the sacrum

2 parts:

- Antero-inferior part of the joint = Synovial joint = articular surfaces are covered with cartilage and separated by a joint space.
- Postero-superior part of the joint = fibrous joint = contains adipose and loose connective tissue + strong interosseous sacroiliac ligament + no overlying cartilage

Musculotendinous

- Latissimus dorsi
- Gluteus maximus
- Piriformis

Ligamentous

- Interosseous sacroiliac ligament
- Anterior sacroiliac ligament
- Dorsal sacroiliac ligament
- Iliolumbar ligament
- Sacrospinous ligament
- Sacrotuberous ligament

MRI Technique:

- Patient position: Supine; head first

Coronal oblique T1 & STIR 3mm Small FOV Parallel to long axis of sacrum	Axial oblique STIR 3mm Small FOV Perpendicular to long axis of sacrum

Usually bilateral and symmetrical

- Enteropathic arthritis
- Crohn disease
- Ulcerative colitis
- Ankylosing spondylitis
- Rheumatoid arthritis 1
- Hyperparathyroidism: not a true sacroiliitis but can mimic appearances
- Osteitis condensans ilii
- Multicentric reticulohistiocytosis
- Whipple disease

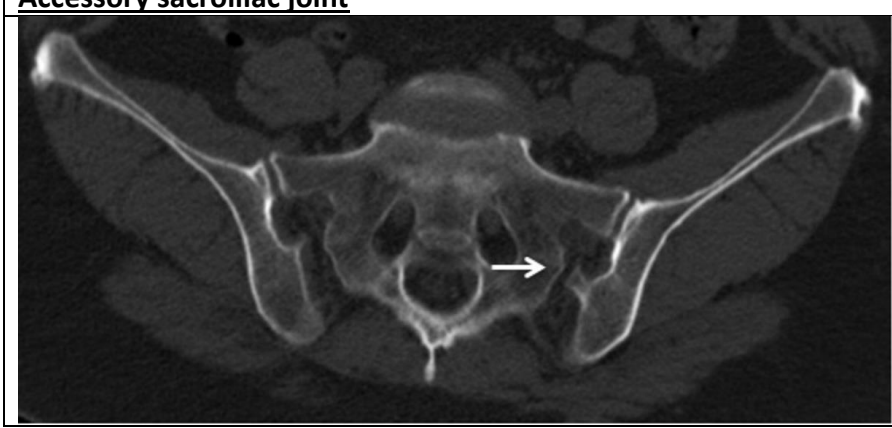
Usually bilateral but asymmetrical

- Gout
- Psoriatic arthritis
- Reactive arthritis (reiter syndrome)
- Osteoarthritis
- Relapsing polychondritis
- Behcet disease
- Sacroiliitis circumscripta

Usually unilateral

- Neoplastic destructive process
- Infective
- Pyogenic septic arthritis
- Tuberculous sacroiliitis
- Brucellosis
- Paraplegia
- Sapho syndrome

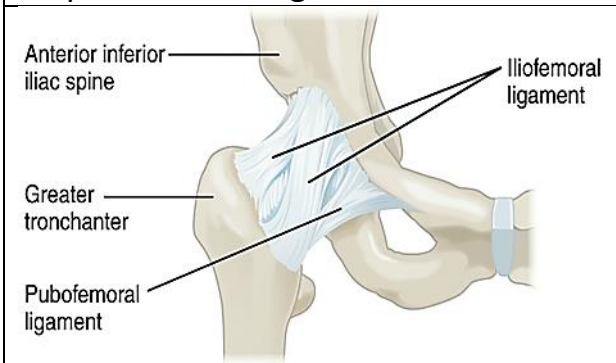
Accessory sacroiliac joint

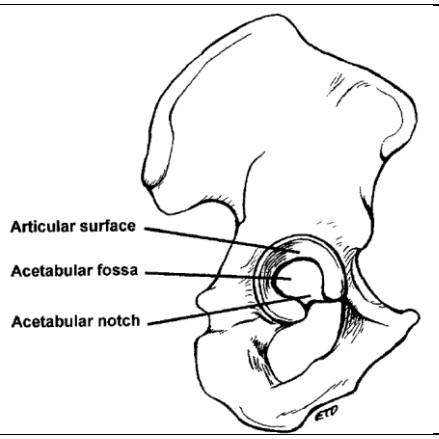


Hip Joint

❖ Anatomy

- Synovial joint “ball and socket joint” between femoral head and acetabulum of pelvis
- The acetabulum is formed by 3 bones of pelvis (ischium, ilium and pubis.
- Between them is Y-shaped cartilaginous growth plate (triradiate cartilage) which is usually fused by age 14-16.
- The acetabular labrum increases the depth of the joint.
- The joint is surrounded by a fibrous capsule, which is attached to the acetabulum, and then attaches to the proximal aspect of the femur 1.
- Thickenings of this capsule constitute ischiofemoral, iliofemoral and pubofemoral ligaments



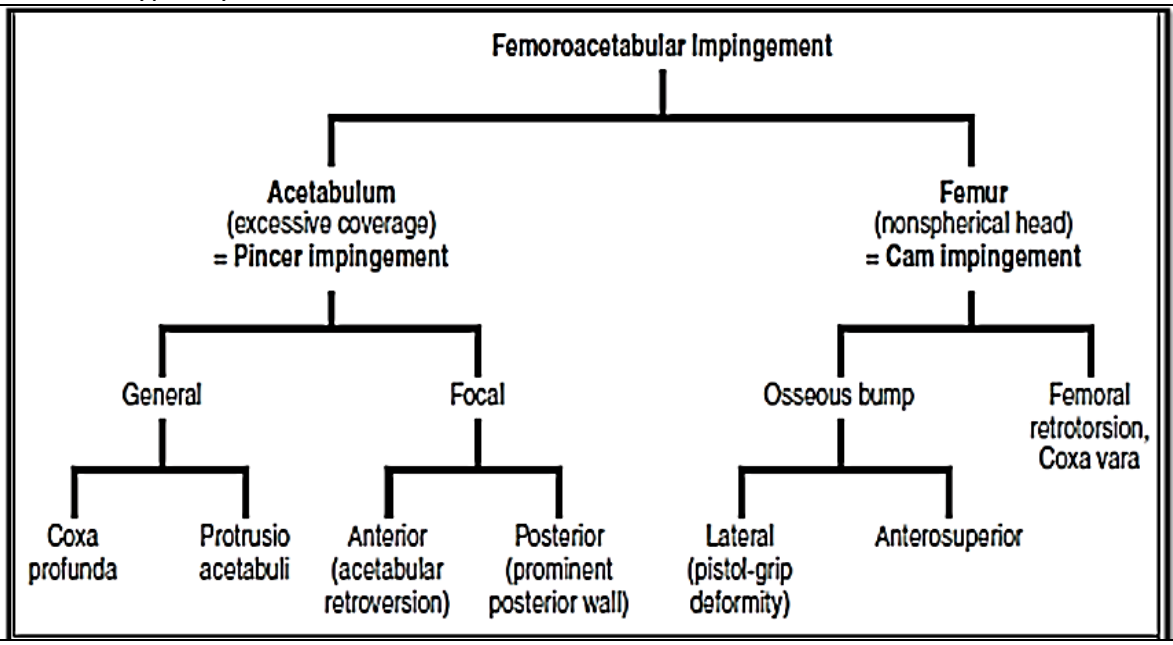


Anteroposterior radiograph of the pelvis
Anterior acetabular wall (dotted line) is continuous with the superior pubic ramus.
Posterior acetabular wall (dashed line) blends with the ischium.

Hip Impingement Syndromes

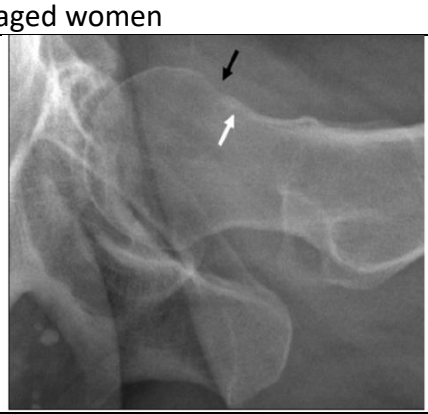
I. Femoro-Acetabular Impingement

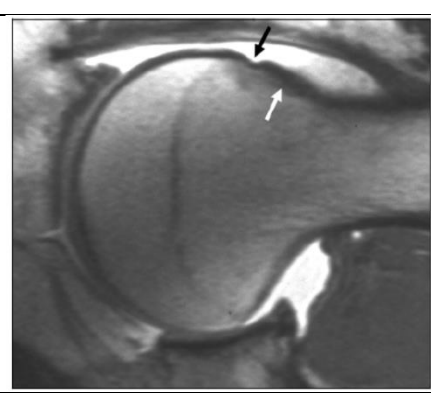
- A major cause of early osteoarthritis of the hip, especially in young and active patients
- It is characterized by an early pathologic contact during hip joint motion between skeletal prominences of the acetabulum and the femur that limits the physiologic hip range of motion, typically flexion and internal rotation.



A) Pincer Type :

- An over-coverage of the femoral head by the acetabulum (coxa profunda) which results in abutment of the femoral neck against the acetabulum.
- More common in middle-aged women



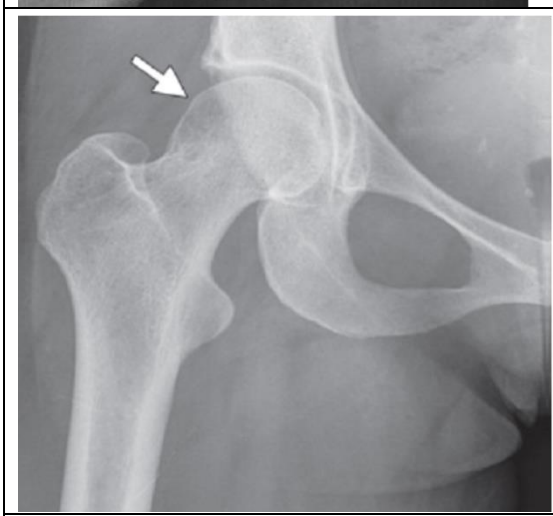
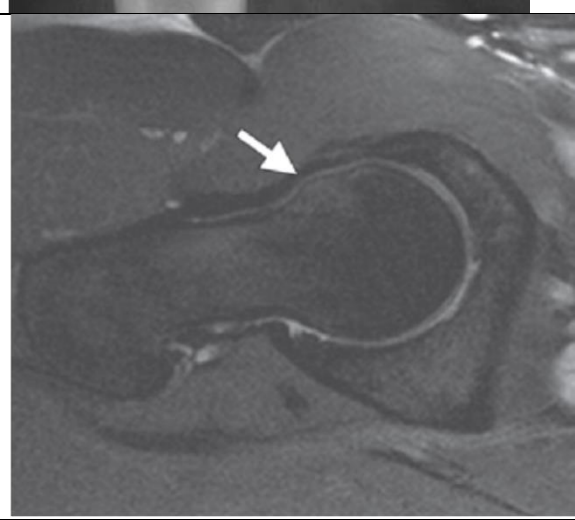


B) Cam Type :

- Femoral cause of femoroacetabular impingement
- More common in younger males.

Triad of:

- Abnormal contour or “bump” of the anterolateral aspect of the femoral head–neck junction
- Anterosuperior labral abnormality
- Anterosuperior acetabular cartilage abnormality (thinning, irregularity and fissuring)

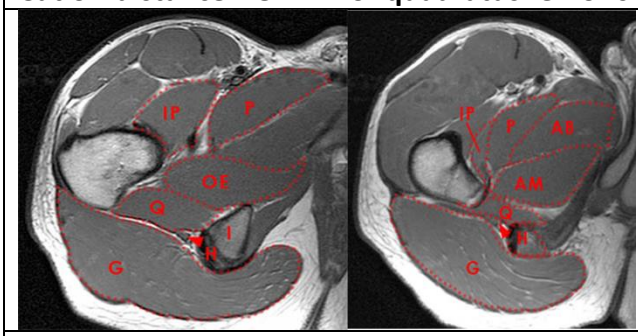
C) Combined Type

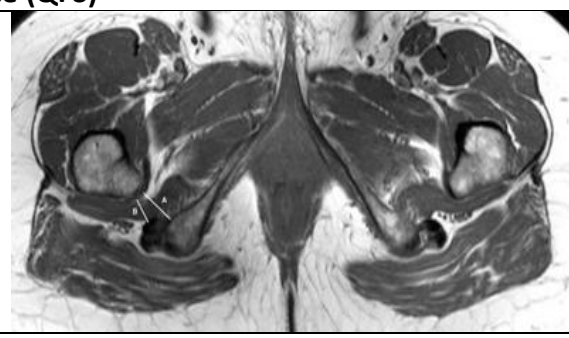
- Mixture of the two occuring together

II. Ischio-Femoral Impingement

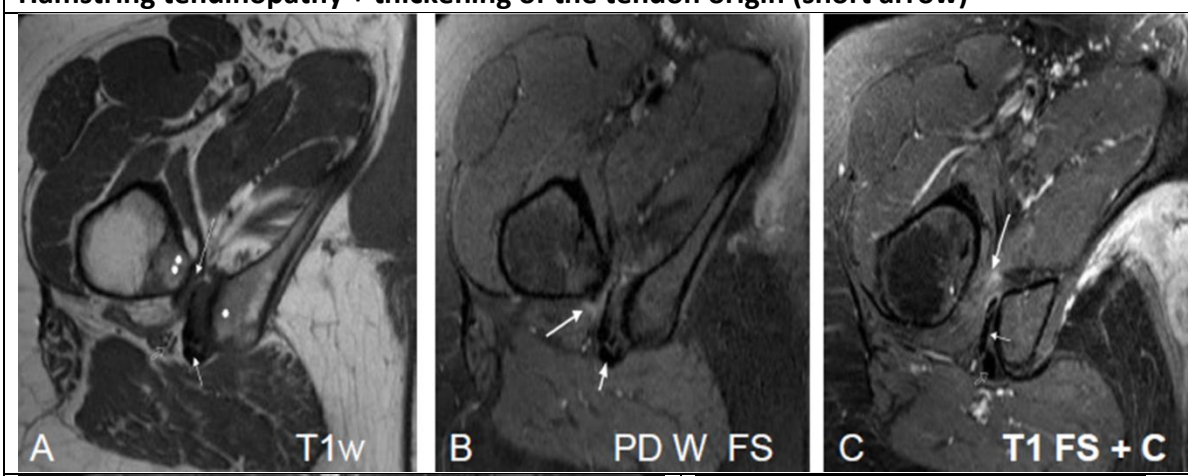
- Caused by abnormal contact between the lesser trochanter of the femur and the ischium.

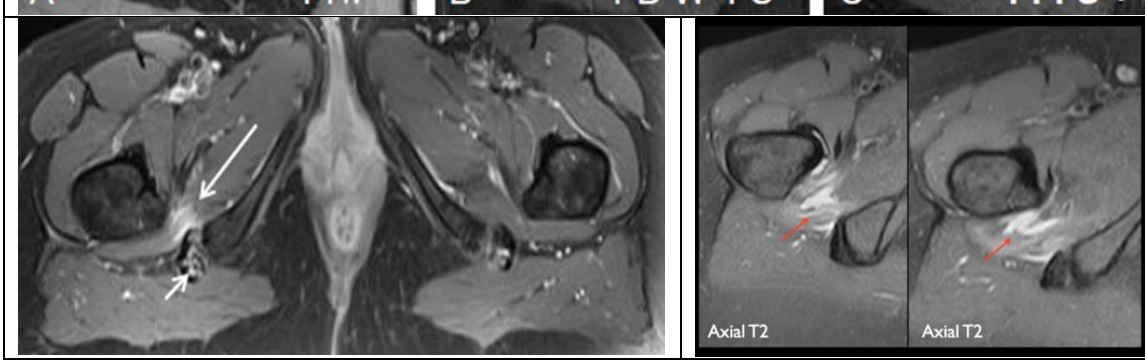
A = Ischio-femoral space (IFS) = 23±8mm
B = Quadratus femoris space (QFS) = 12±4mm
Cut off distance < 17 mm for Ischio-femoral space
Cut off distance < 8 mm for quadratus femoris space (QFS)





Narrowing of the QFS (3mm) (white arrow)
Edema + Enhancement of QFM
Hamstring tendinopathy + thickening of the tendon origin (short arrow)





Acetabular Labrum

- The acetabular labrum is a horseshoe-shaped fibrocartilaginous structure attached to the acetabular rim
- Analogous to the glenoid labrum in the shoulder.
- The labrum is 2–3 mm in thickness
- Triangular in cross-section, broad at its base and pointed at its lateral margin.
- The base of the labrum is immediately apposed to the outer margin of the acetabular cartilage, forming the chondrolabral junction
- MRI: labrum is normally hypointense in signal with all pulse sequences
- MR arthrography superior sensitivity and specificity for detection of labral tears

Proposed pathophysiologic mechanisms of labral tears include:

FAI, trauma, hip dysplasia, hyperlaxity/subluxation, repetitive overuse injury, and degeneration

Labral tears at nonarthrographic MRI:

- Linear increased signal on fluid-sensitive images traversing the substance of the labrum or at the chondrolabral junction.

Labral tears at MR Arthrography:

- Labral tears are confirmed by contrast material extending into the tear defect

Secondary findings of labral tears

- Adjacent cartilage abnormalities
- Subchondral edema
- Subchondral cyst formation
- Paralabral cyst formation
- Os acetabuli = labral injury with associated labral ossification

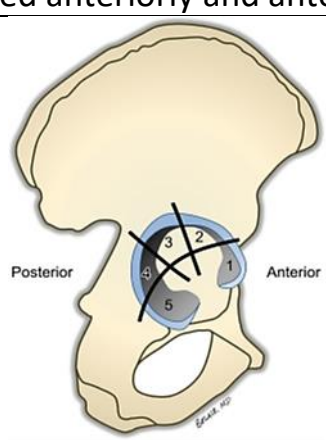
Types:

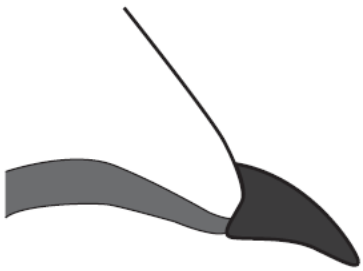
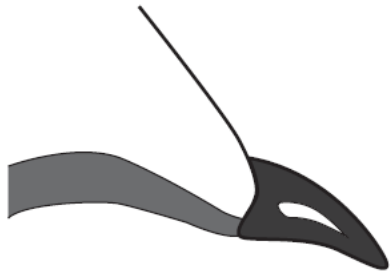
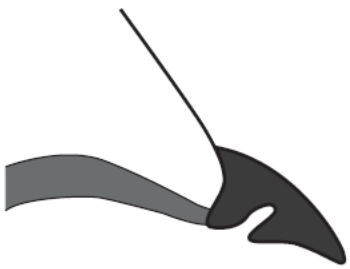
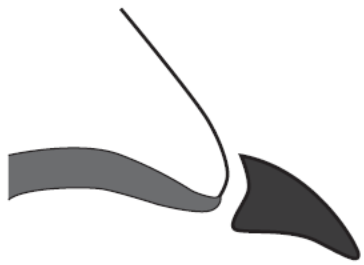
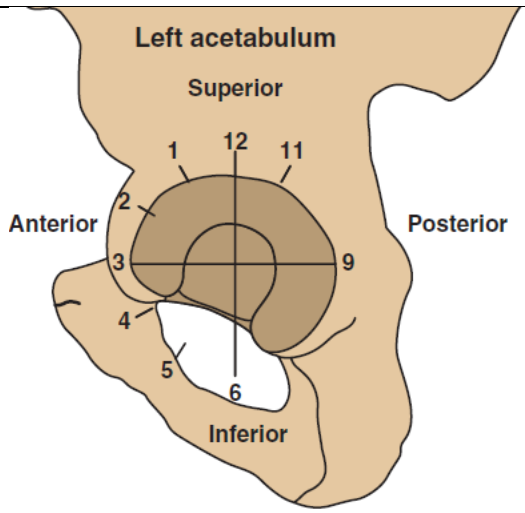
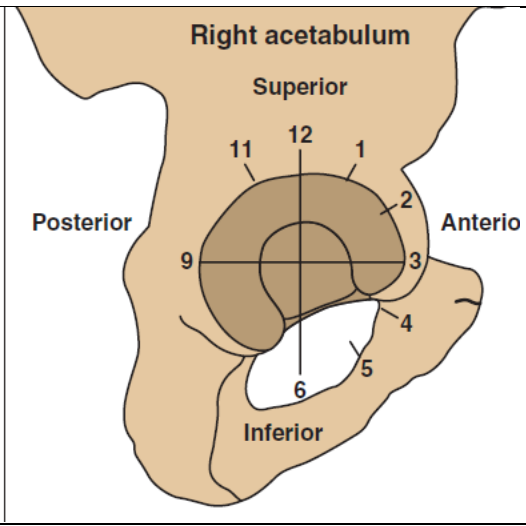
- Undersurface (partial-thickness)
- Detached (full-thickness)

Location:

- Labral tears are most frequently encountered anteriorly and anterosuperiorly

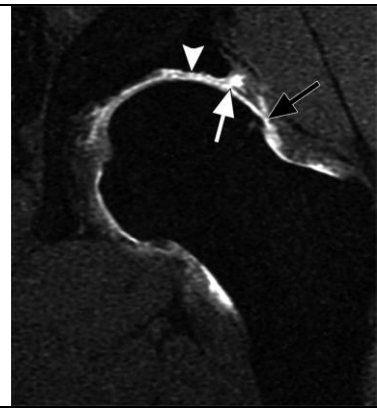
Zone 1 = anterior acetabulum
Zone 2 = anterosuperior acetabulum
Zone 3 = superior acetabulum
Zone 4 = posterosuperior acetabulum
Zone 5 = posterior acetabulum.



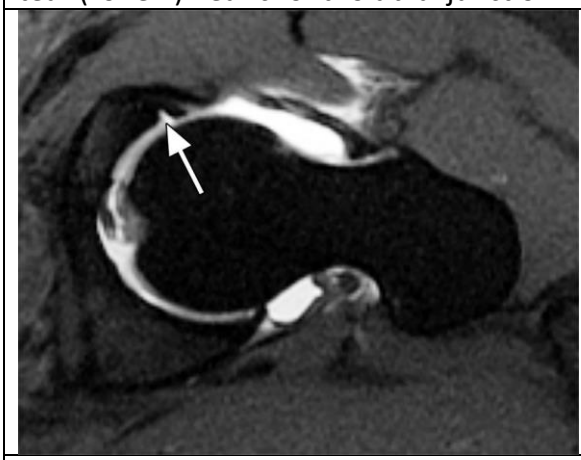
Normal Labrum	Intra-substance Labral Tear
	
Partial Thickness Labral Tear	**Full Thickness Labral Tear**
	
Blankenbaker Clock Face Of Labral Tears	
	

Triad of cam-type FAI:

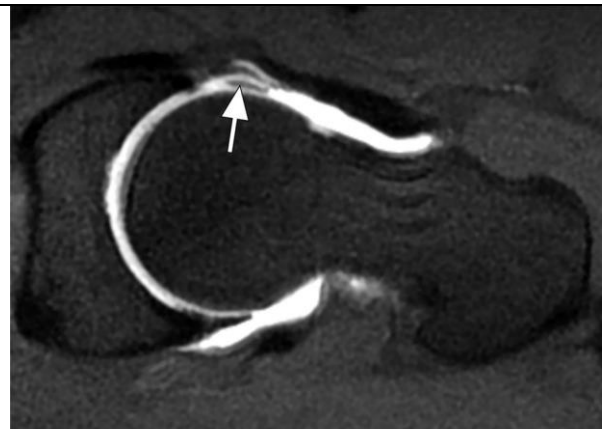
- ✓ Osseous prominence (black arrow) at the anterosuperior femoral head-neck junction.
- ✓ Full-thickness tear of the superior labrum (zone 3) at the chondrolabral junction (white arrow)
- ✓ High-grade partial thickness cartilage loss (grade 3 chondrosis) is noted at the superior acetabulum (zone 3) (arrowhead).



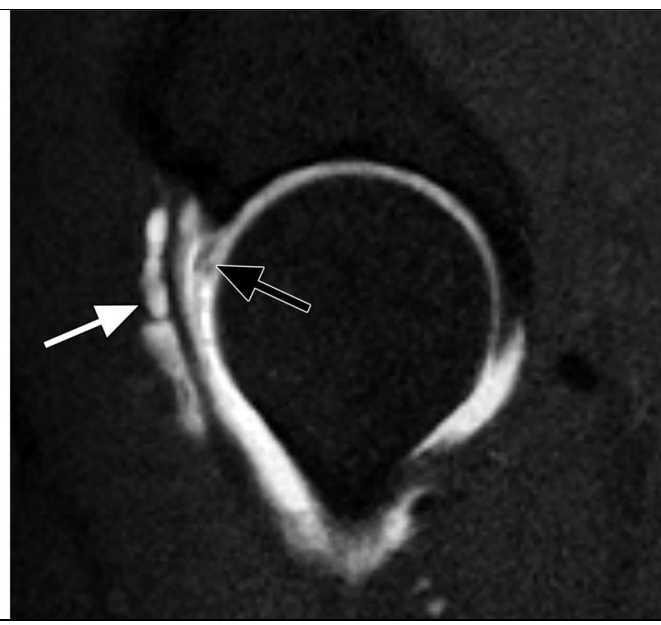
Partial-thickness undersurface anterior labral tear (zone 1) near chondrolabral junction.

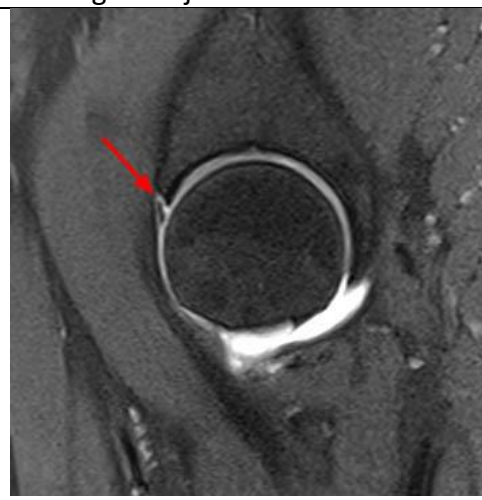
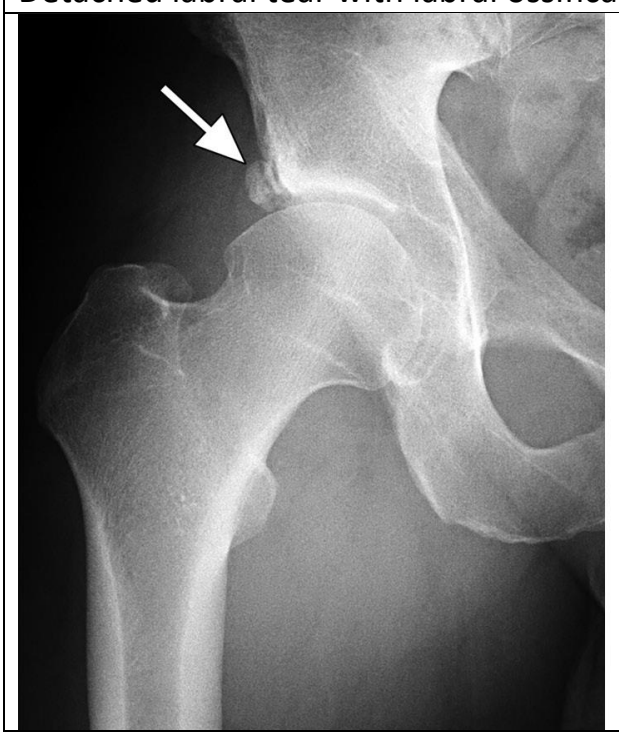


Detached anterior labral tear



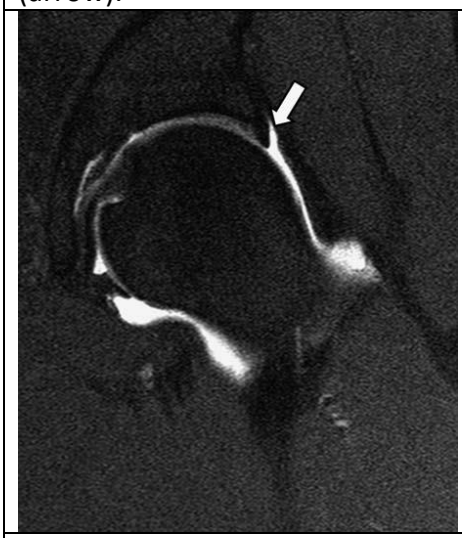
Paralabral cysts



Paralabral cyst	Sagittal T1-FS MR arthrogram image demonstrates contrast fully extending across the base of the labrum at the labral-cartilaginous juncture = Full thickness tear
	
Detached labral tear with labral ossification = “os acetabuli”	
	

❖ Normal Variants Of Labrum

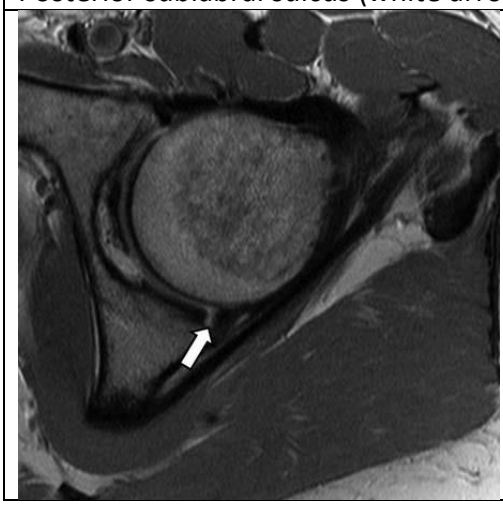
Coronal T1 fat-saturated MR arthrogram
Superior perilabral recess between the high attachment of hip joint capsule and labrum (arrow).



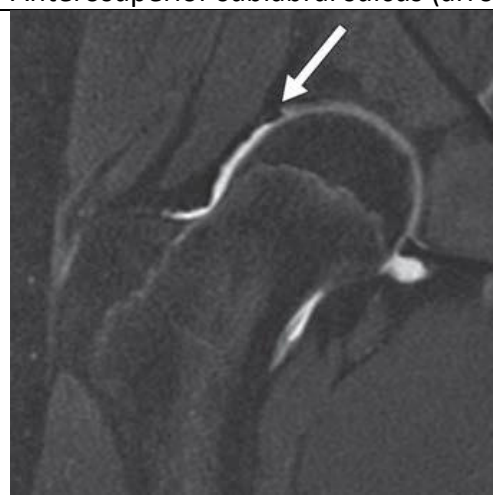
Coronal T2 fat-saturated image
Large type I supraacetabular fossa seen as a large focal defect in the acetabular cartilage and subchondral bone (arrow).

Sublabral Sulcus

Axial PD image
Posterior sublabral sulcus (white arrow).



Coronal PD FS image
Anterosuperior sublabral sulcus (arrow),



Articular Cartilage

MRI: Hyaline cartilage is characterized by:

- Low-signal-intensity superficial layer
- Higher-signal-intensity transitional layer
- Low-signal-intensity deep and calcified layers
- Adjacent to the subchondral bone

Radiographs demonstrate secondary signs of cartilage loss:

- Joint space narrowing
- Subchondral sclerosis
- Marginal osteophyte formation.

MR arthrography: Chondral abnormalities are recognized as

- Contour defects
- Thinning compared with normal adjacent cartilage
- And/or focal signal intensity abnormality.

Non-MR-Arthrogram: Secondary findings

- Subchondral edema
- subchondral cyst formation

Modified Noyes scale:

Grade 0 = normal cartilage
Grade 1 = cartilage heterogeneity and hyperintensity on T2
Grade 2 = partial-thickness defect involving < 50% of normal cartilage thickness
Grade 3 = partial-thickness defect involving > 50% of normal cartilage thickness
Grade 4 = full-thickness defect

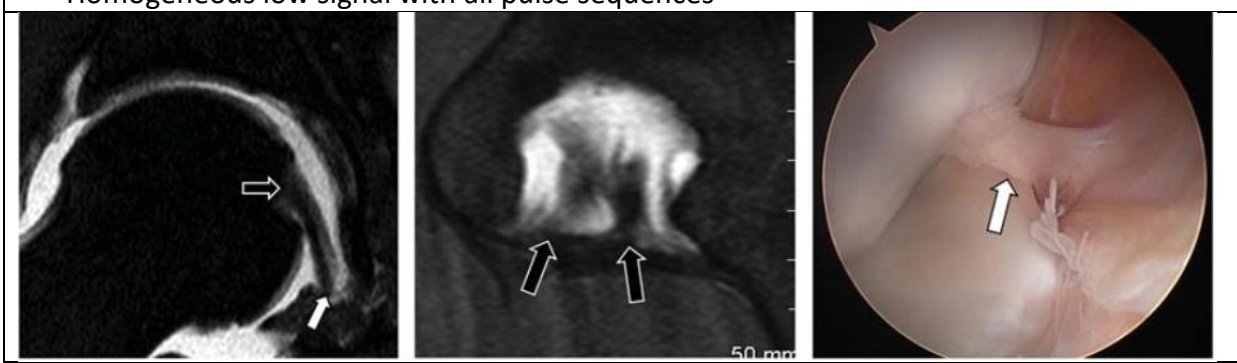
Full-thickness anterosuperior acetabular cartilage loss	Partial-thickness cartilage defect at the superior acetabulum (zone 3). Contrast material undermines adjacent cartilage laterally (arrow), = delaminating chondral flap.

Ligamentum Teres

- 30–35-mm long cord-like band of tissue
- Arising from the transverse acetabular ligament
- Attaching proximally to the fovea capitis

MRI Of Normal Ligamentum Teres

- Oval structure
- Smooth contours
- Homogeneous low signal with all pulse sequences

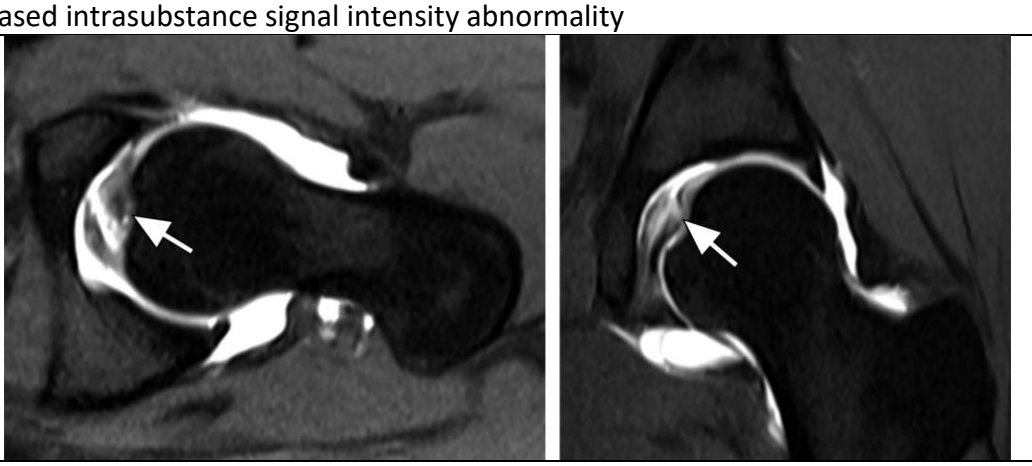


MRI of Complete Tear:

- Complete Loss of continuous cord-like structure
- High signal intensity within the ligament at sites remote from the tear

MRI of Partial Tear:

- Focal partial loss of continuity
- Increased intrasubstance signal intensity abnormality

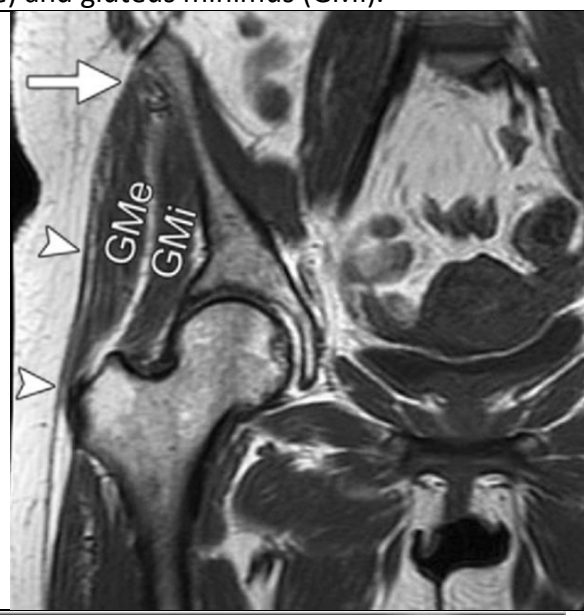


Lateral Hip Pain

A) Proximal iliotibial band (ITB) syndrome

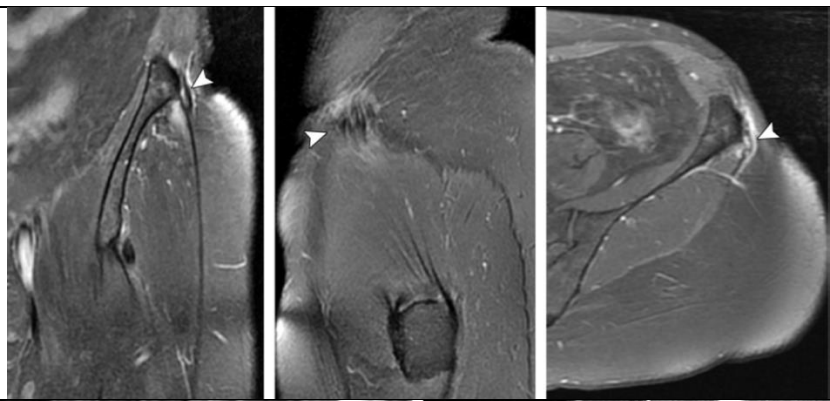
Normal ITB:

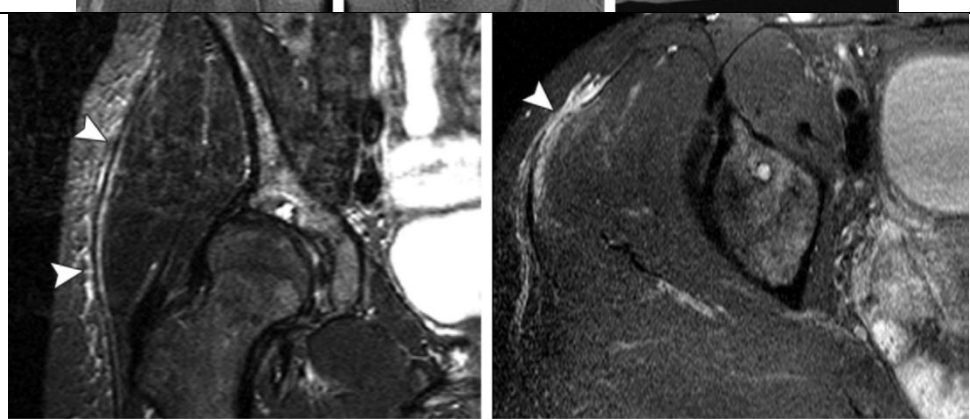
- ITB appears as a thin aponeurotic band (arrowheads)
- Attaching proximally to the iliac crest
- Passing over the greater trochanter of the proximal femur.
- At the level of the greater trochanter, the ITB is surrounded by fat
- Deep to the ITB are the gluteus medius (GMe) and gluteus minimus (GMi).

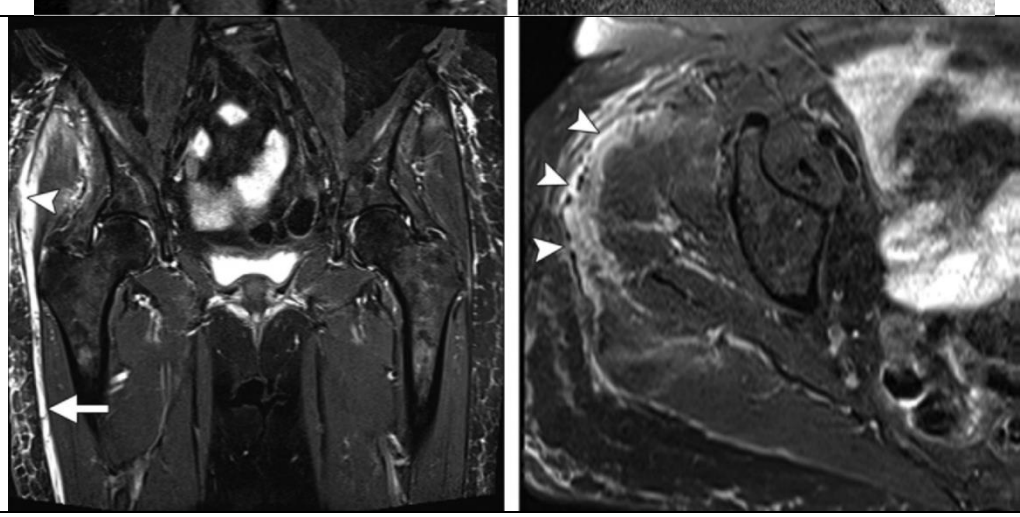


Imaging findings:

- Partial tear = Thickening + hyperintense intrasubstance signal + focal tearing in ITB at its proximal attachment to the iliac tubercle
- Surrounding soft-tissue edema.
- Edema of the surrounding subcutaneous fat
- Edema within the underlying gluteus medius
- No bone marrow edema





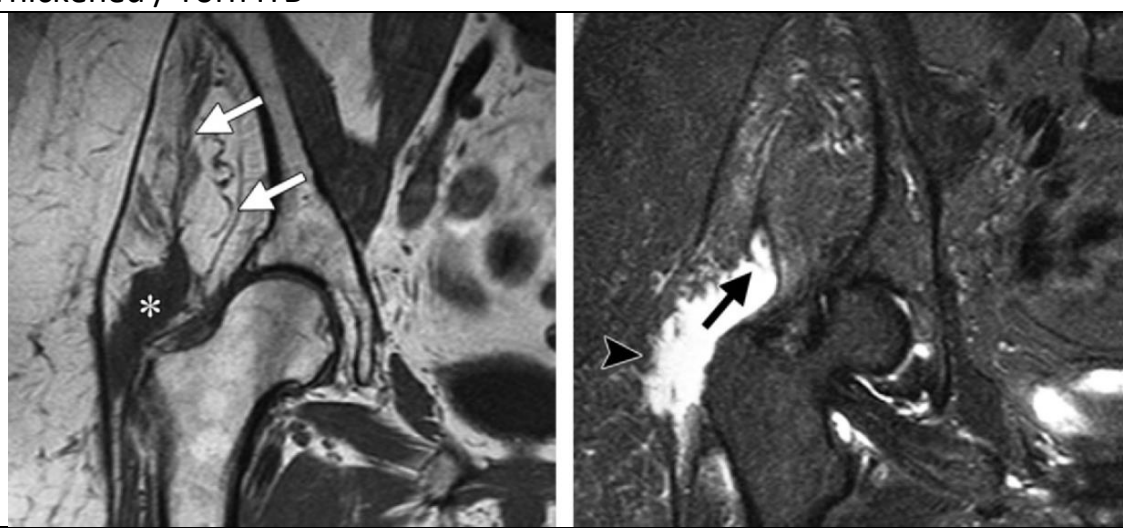


B) Greater Trochanteric Pain Syndrome (GTPS) Rotator Cuff Tears Of The Hip

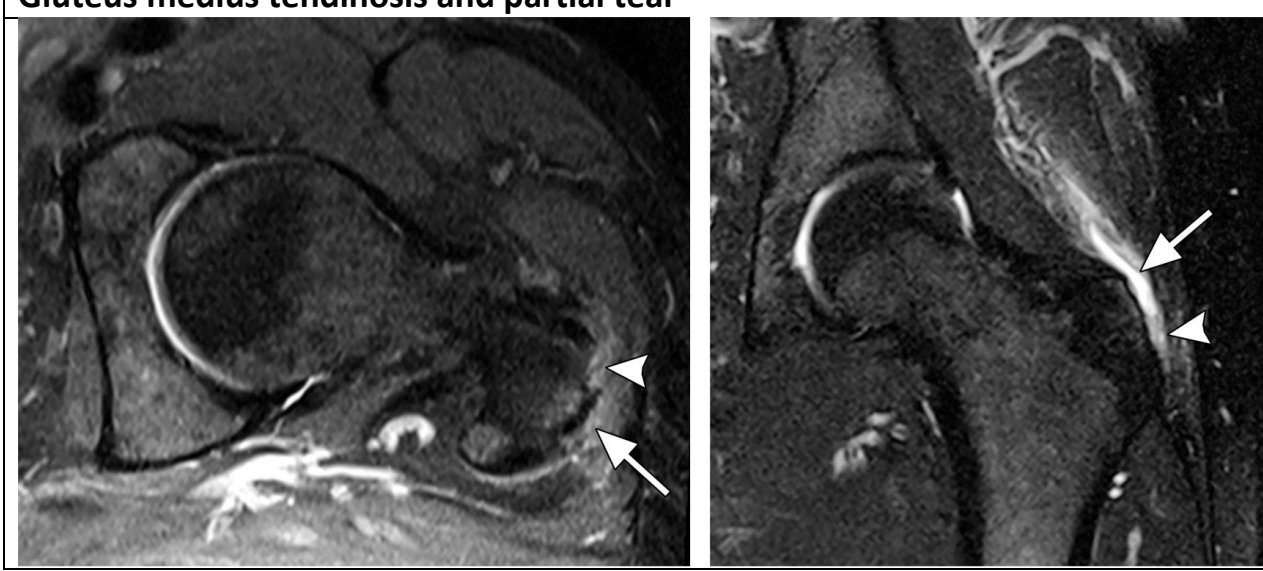
- GTPS typically affects older women in their 60s to 70s

Imaging findings:

- Tears / Tendinopathy of gluteus minimus and medius tendons (hip abductor tendons) + fatty atrophy
- Greater trochanteric bursitis + protruded through fascial defects of the overlying ITB
- Thickened / Torn ITB



Gluteus medius tendinosis and partial tear



C) Snapping Hip Syndrome

Snapping hip syndrome is simply an audible snapping sound produced during motion of the hip.

Extra articular causes

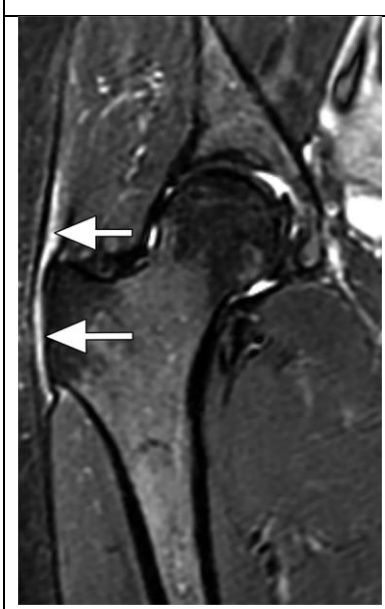
- Lateral:
  - Iliotibial band snapping over the greater trochanter
  - Gluteus maximus snapping over the greater trochanter
- Medial
  - Iliopsoas tendon snapping over the iliopectineal eminence

Intra articular causes

- Synovial osteochondromatosis
- Intraarticular loose bodies
- Acetabular labral tears
- Osteochondral fractures
- Transient subluxation of the femoral head

External Snapping Hip

Coronal STIR image shows mild thickening of the iliotibial band with subjacent fluid and edema at the level of the greater trochanter (arrows), from repetitive snapping of the iliotibial band over the greater trochanter.

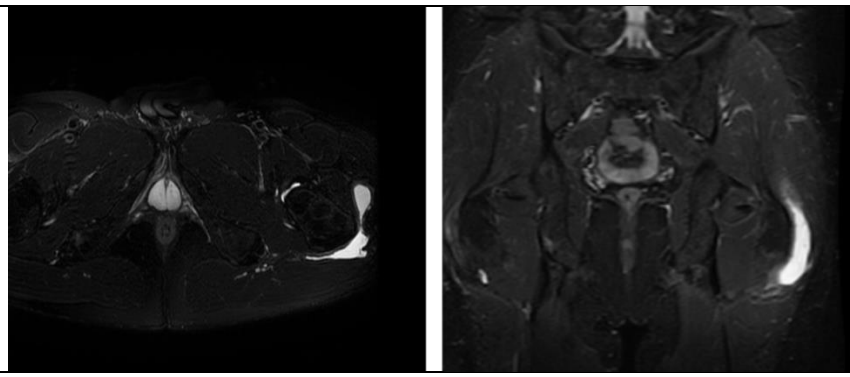


Axial T2-FS image shows moderate left iliopsoas peritendinitis and bursitis at the level of the acetabulum (arrow).
The iliopectineal eminence is noted anteriorly (arrowhead), which acts as a fulcrum over which the iliopsoas tendon snaps during hip motion.

D)Greater Trochanteric Bursitis

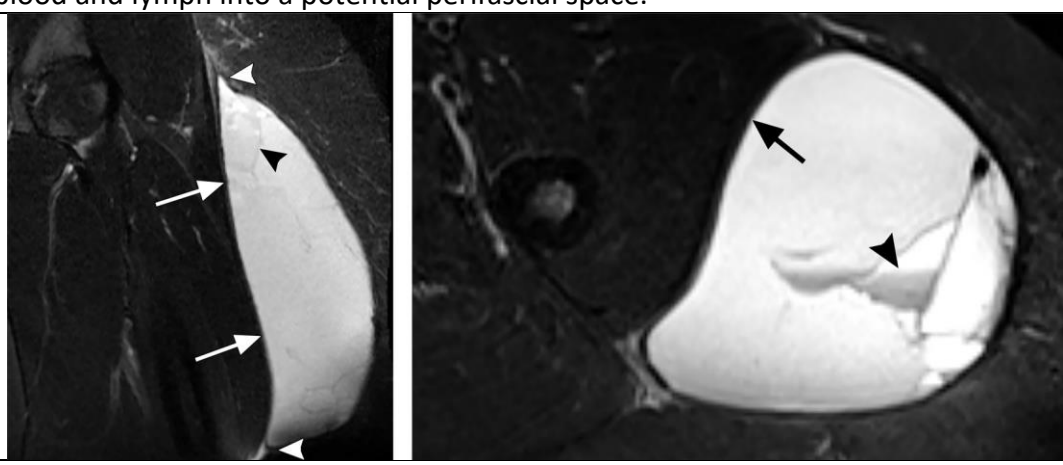
Imaging findings:

Bright T2 signal within the bursa often with fluid or abnormal signal within and around the hip abductor tendons

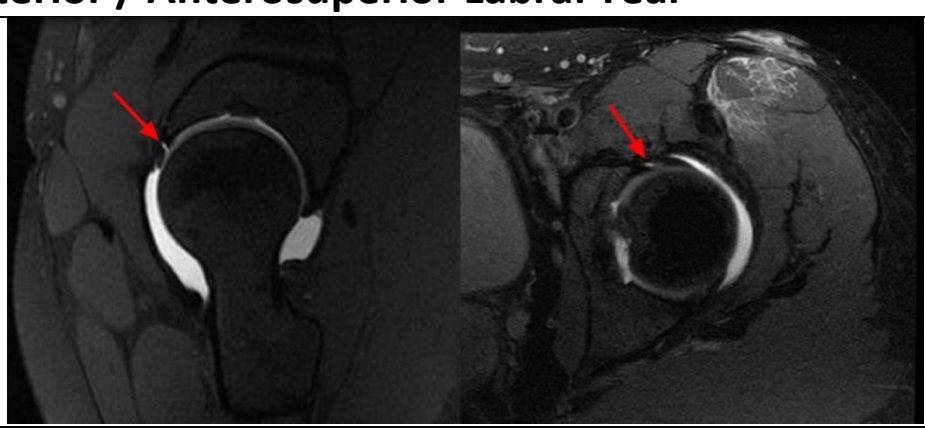


E) Morel-Lavallée Lesions

- Morel-Lavallée lesions are closed degloving softtissue injuries, in which there is separation of subcutaneous fat from the underlying fascia due to an abrupt shearing injury.
- Perforating vessels and lymphatics that pierce the fascia are disrupted, resulting in drainage of blood and lymph into a potential perifascial space.



F) Anterior / Anterosuperior Labral Tear



Groin Injury in Athletes

Differential Diagnosis of Groin Pain in Athletes
Visceral causes
Inguinal hernia
Other abdominal hernias
Testicular torsion
Hip-associated causes
Acetabular labral tear and femoroacetabular impingement
Osteoarthritis
Snapping hip syndrome and iliopsoas tendonitis
Avascular necrosis
Iliotibial band syndrome
Pubic symphyseal causes
Rectus abdominis strain
Adductor muscle-tendon dysfunction
Rectus abdominis–adductor longus aponeurosis tear
Osteitis pubis
Infectious causes
Septic arthritis
Osteomyelitis
Pelvic inflammatory disease
Prostatitis
Epididymitis and orchitis
Herpes infection
Inflammatory causes
Endometriosis
Inflammatory bowel disease
Pelvic inflammatory disease
Traumatic causes
Stress fracture
Tendon avulsion
Muscle contusion
Baseball pitcher–hockey goalie syndrome
Developmental causes
Apophysitis
Growth plate stress injury or fracture
Legg-Calvé-Perthes disease
Developmental dysplasia
Slipped capital femoral epiphysis
Neurologic causes
Nerve entrapment syndromes (eg, ilioinguinal nerve)
Referred pain
Sacroiliitis
Sciatic entrapment (piriformis syndrome)
Hamstring strain
Knee pain
Neoplastic causes
Testicular carcinoma
Osteoid osteoma

MRI TECHNIQUE of Pubic Bone:

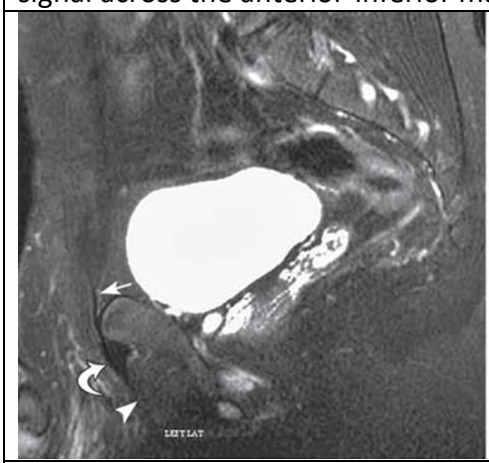
- Coronal T1 (FOV = 28 – 32 cm)
- Coronal STIR (FOV = 28 – 32 cm)
- Axial oblique T1 (FOV = 20 cm)
- Axial oblique T2 FS (FOV = 20 cm)
- Sagittal STIR (FOV = 20 cm)

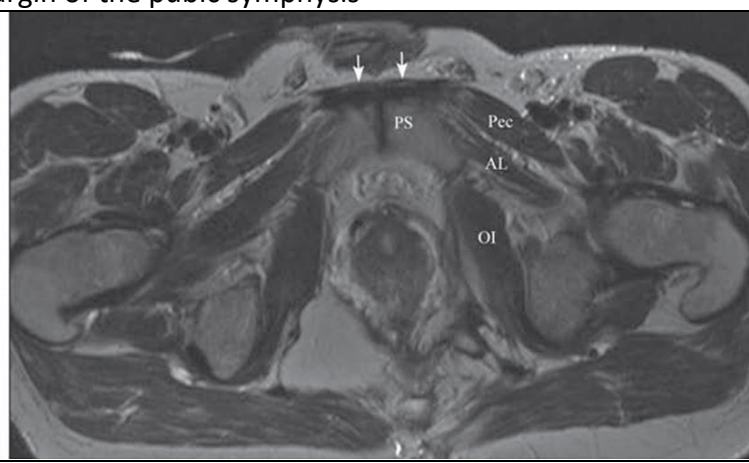
A) Atheletic Pubalgia

Clinical term used to describe injuries involving

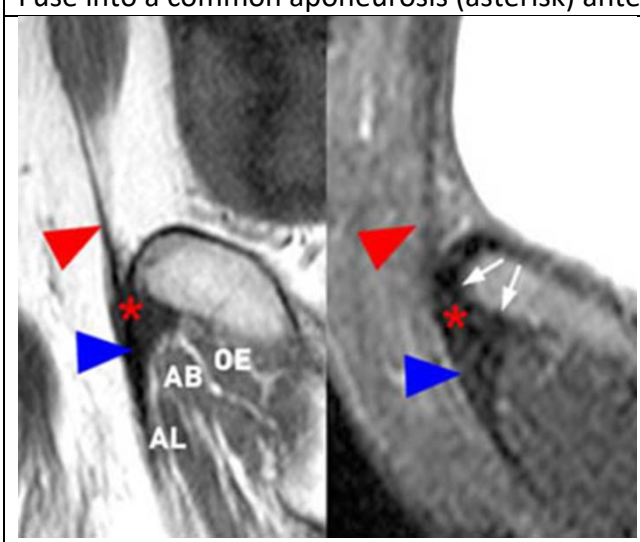
- **Rectus abdominis pubic insertion**
- **Hip adductor muscles and tendon origins**
- **Pubic symphysis**

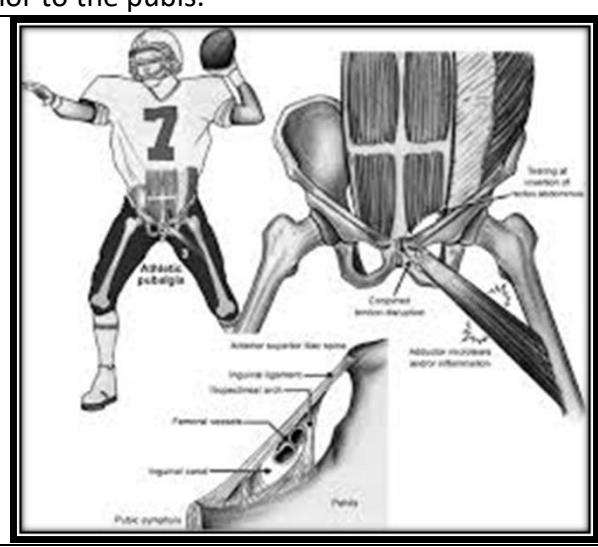
The rectus abdominis–adductor longus (AL) aponeurosis (arrows) appears as a band of low signal across the anterior-inferior margin of the pubic symphysis





1-2 cm lateral to symphysis pubis:
The lateral tendons of the rectus abdominis (red arrowhead)
The adductor longus (blue arrowhead)
Fuse into a common aponeurosis (asterisk) anterior to the pubis.

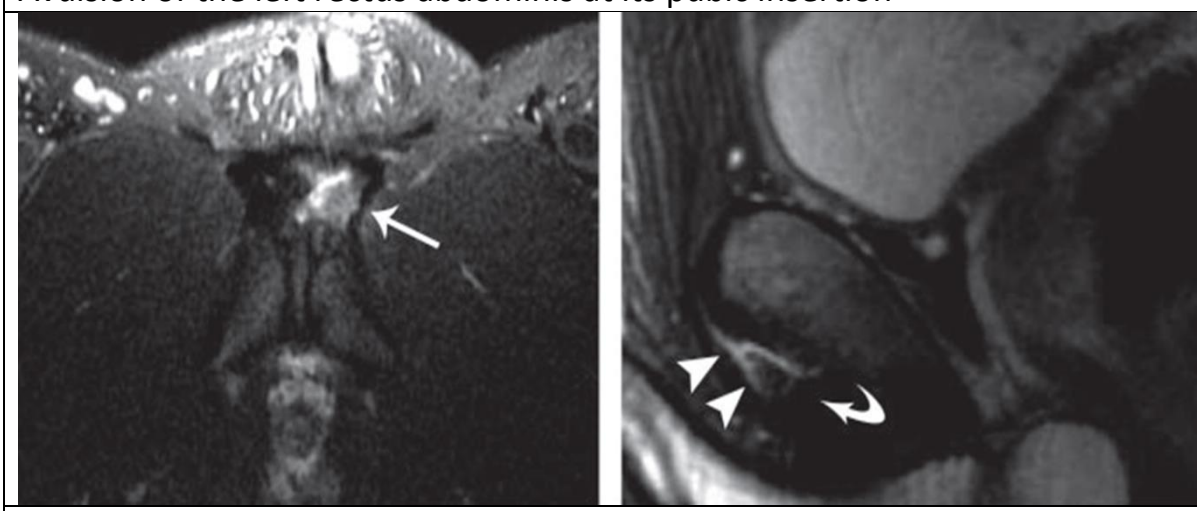




Radiological Findings:

- Rectus abdominis insertional injury
- Adductor muscle strain
- Adductor longus tendon injury
- Rectus abdominis–adductor aponeurosis injury
- Symphysis marrow edema
- Ostitis Pubis
- Secondary cleft sign: Abnormal curvilinear fluid signal intensity extending inferolaterally from the inferior aspect of the symphysis

Avulsion of the left rectus abdominis at its pubic insertion

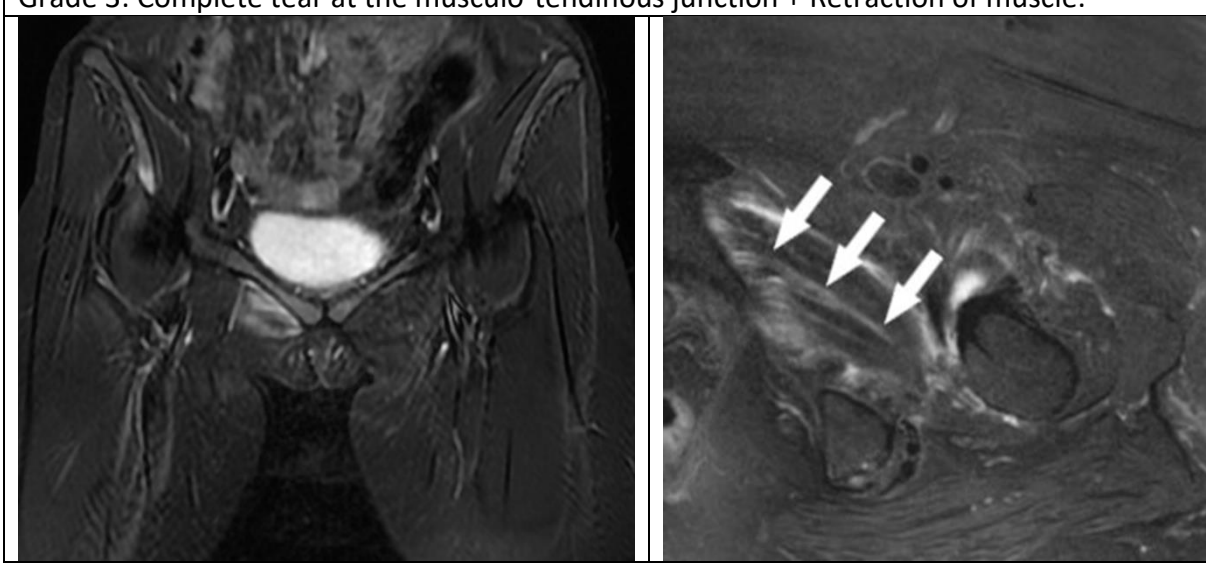


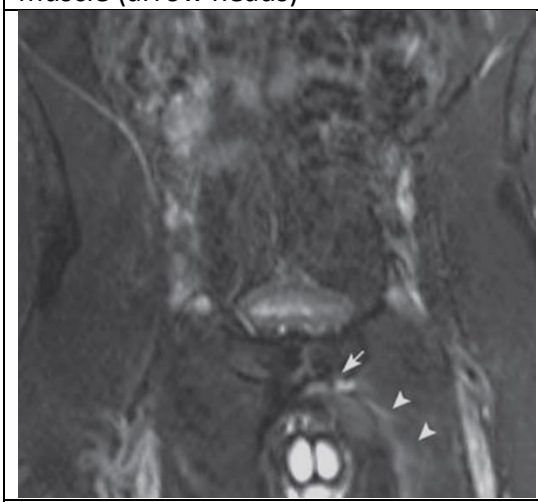
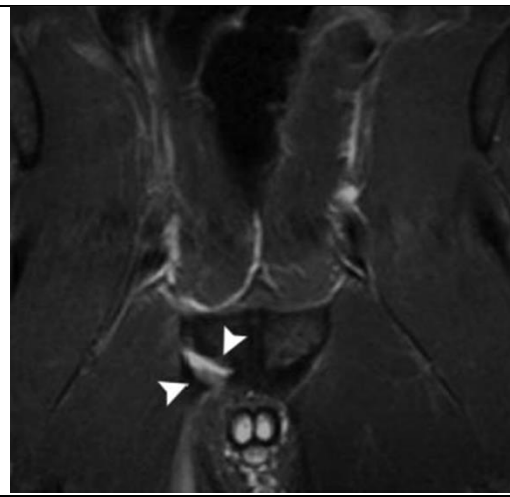
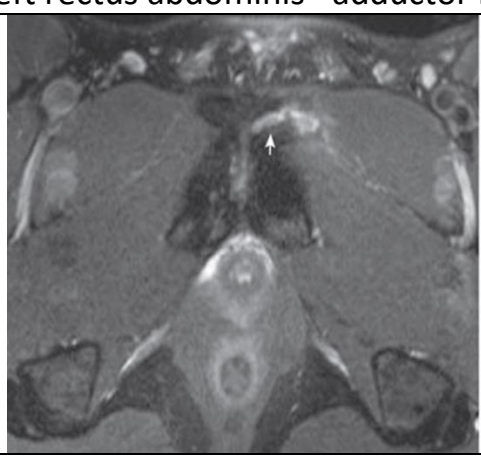
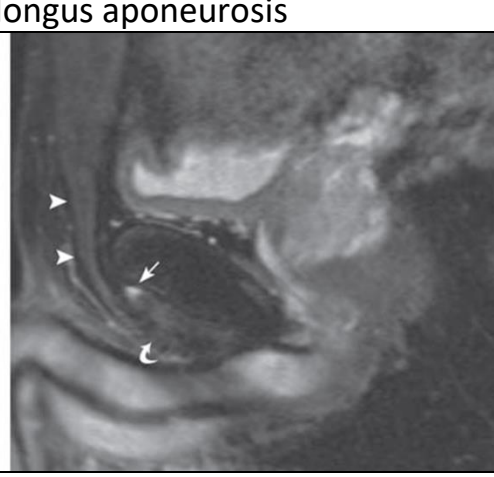
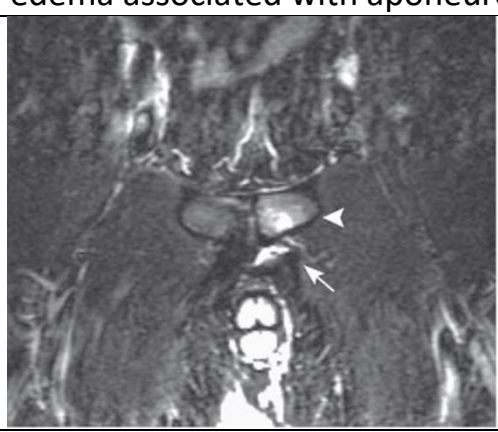
Adductor Muscle Strain

Grade 1: Feather like pattern of edema

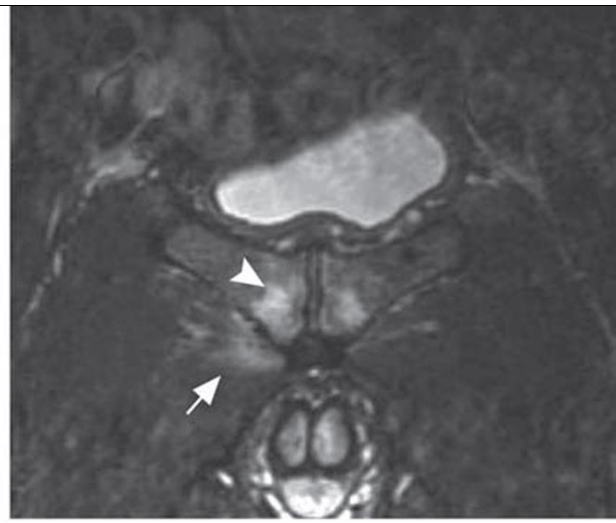
Grade 2: edema + Fluid signal within and around the muscle + No complete tear or retraction.

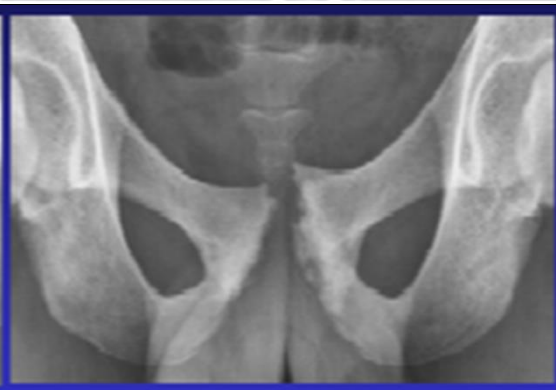
Grade 3: Complete tear at the musculo-tendinous junction + Retraction of muscle.



Secondary cleft sign alongside the left pubic body (arrow) Grade 1 strain of the left adductor longus muscle (arrow heads)	Secondary cleft sign (arrowheads) Complete avulsion of the common adductor longus tendon at its origin.
	
Tear of left rectus abdominis– adductor longus aponeurosis	
	
Marrow edema associated with aponeurosis injury	
	

Ostitis Pubis

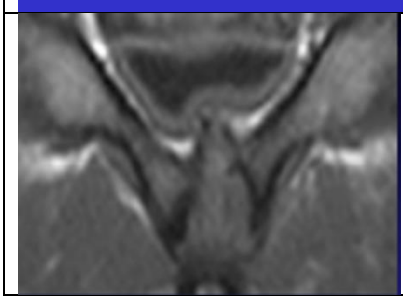


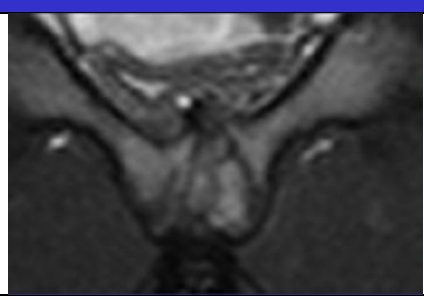


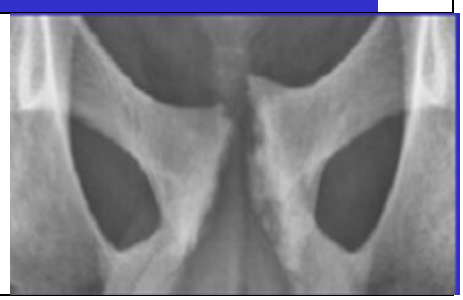
Normal

Osteitis Pubis

Osseous hypertrophy and/or subchondral resorption.

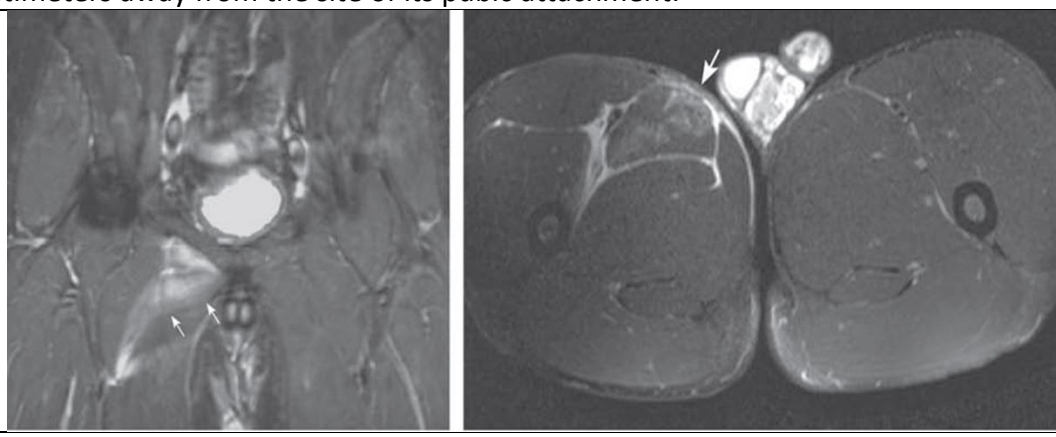






B) Sports Hernia
Hockey Goalie–Baseball = Pitcher Syndrome

- Herniation of the adductor longus muscle belly through a myofascial defect (arrow) several centimeters away from the site of its pubic attachment.

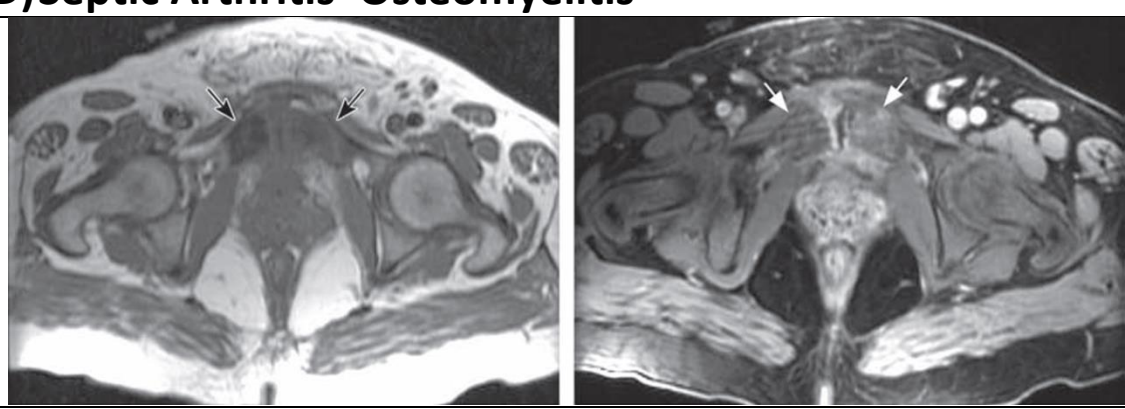


C) Pubic Stress Fracture

Parasymphyseal Stress Fracture

Left superior pubic ramus (arrow) stress fracture

D) Septic Arthritis–Osteomyelitis



Posterior Hip Pain

Gluteal Pain / Buttock Pain

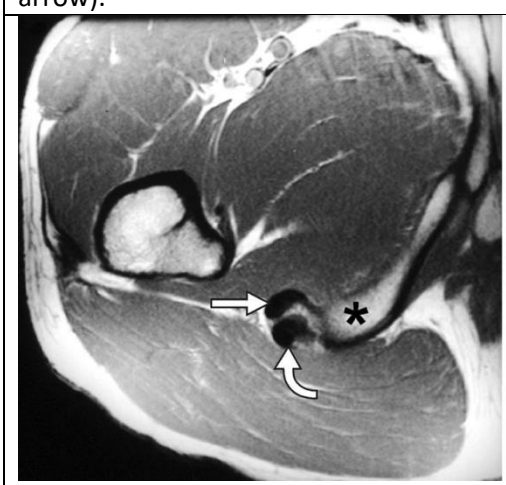
Differential Diagnosis for Posterior Thigh Pain

- Hamstring strain
  - Acute
  - Recurrent
  - Chronic
- Ischial tuberosity disease
  - Avulsion fracture
    - Acute
    - Chronic or nonunited
  - Apophysitis
  - Painful nonunited apophysis
- Hamstring enthesopathy
  - Proximal
  - Distal (tenosynovitis)
- "Hamstring syndrome" (pain localized to the ischial tuberosity and radiating down the hamstring muscle during or after exercise)

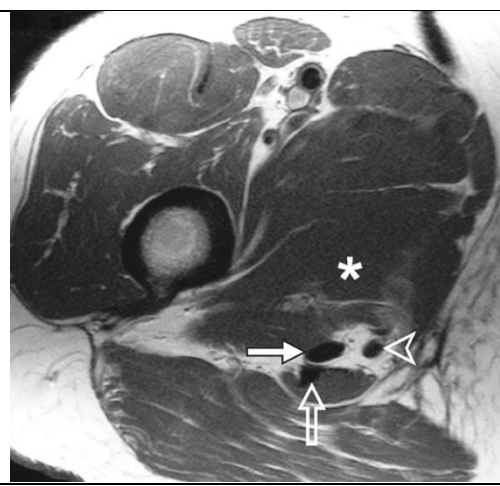
- Referred pain
  - Lumbar spine
  - Sacroiliac joints
  - Pubic symphysis
  - Nerve tissue, meninges
  - Gluteal muscles
- Hamstring contusion
- Myositis ossificans
- Bursitis
  - Ischiogluteal
  - Pes anserinus
  - Semimembranosus
  - Trochanteric
- Ligament strain
  - Sacrotuberous
  - Sacrospinous

Hamstring Muscle Complex:

Ischial tuberosity (*)
Conjoint tendon of the biceps femoris and semitendinosus muscles posteromedially (curved arrow)
Semimembranosus muscle anterolaterally (straight arrow).

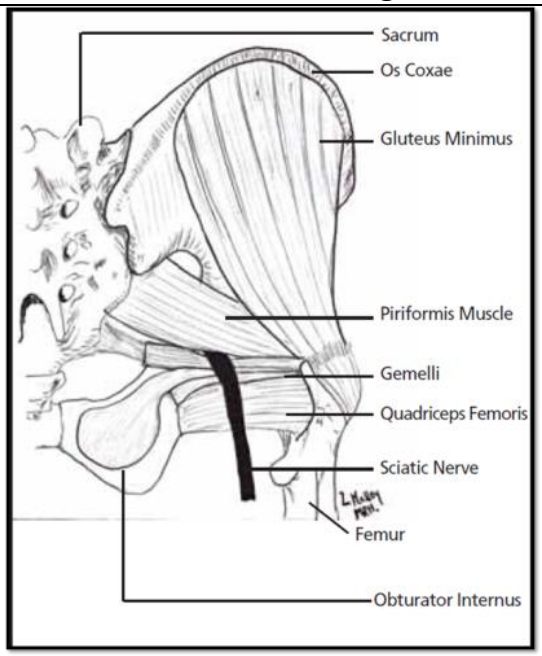


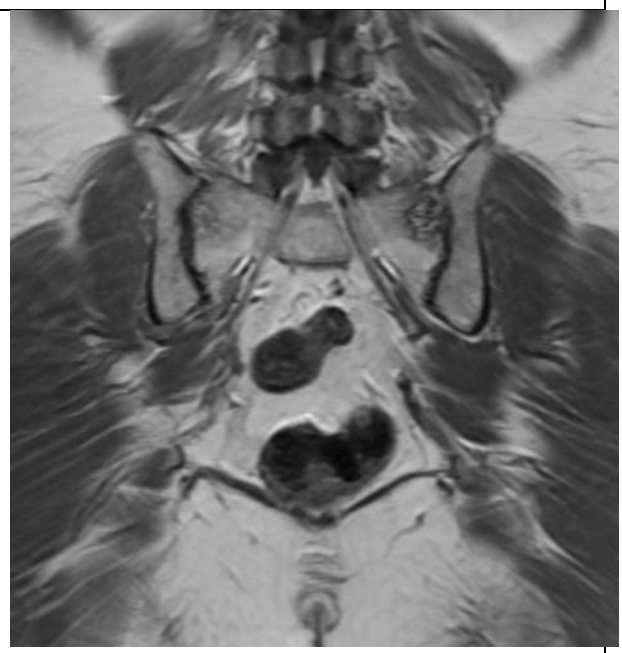
Semitendinosus muscle (solid arrow)
Semimembranosus tendon (arrowhead)
Adductor magnus tendon (open arrow) lies anterior to the conjoint tendon.



A) Piriformis Syndrome

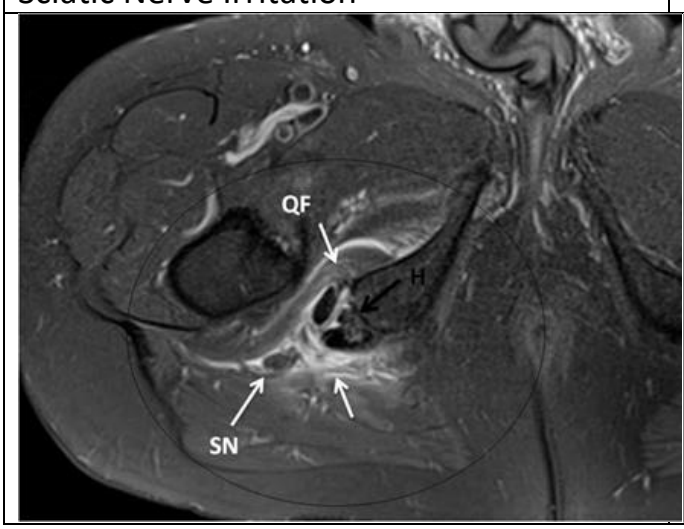
- The piriformis syndrome refers to a rare entrapment neuropathy of the sciatic nerve in the greater sciatic notch resulting in radicular pain radiating into the buttock and hamstrings.



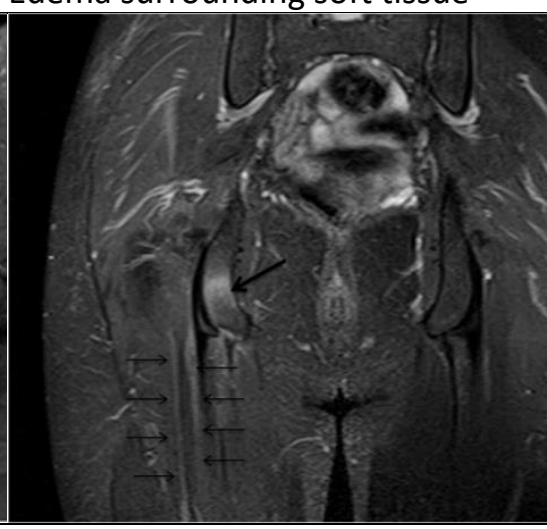


B) Hamstring Syndrome

Proximal Hamstring Tendinopathy
Sciatic Nerve Irritation



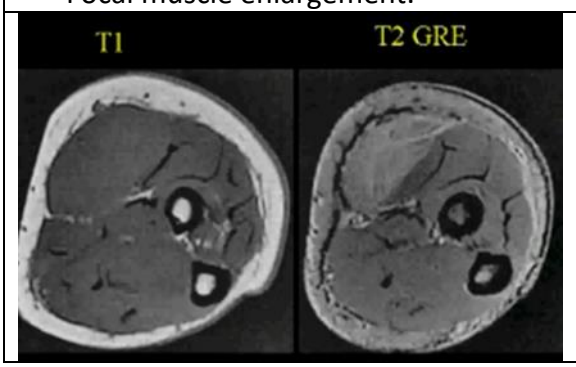
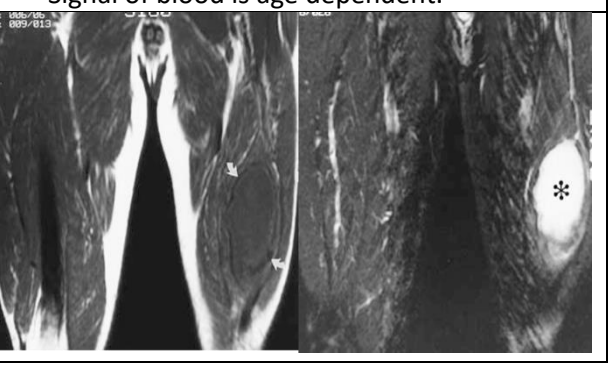
Edema in the ischial tuberosity
Edema surrounding soft tissue



C) Hamstring Musculotendinous Injuries

i. Direct Muscle Injury:

- Blunt trauma => Muscle Contusion.
- Penetrating trauma => Muscle Laceration

❖ Contusion = Interstitial hemorrhage:	❖ Intramuscular Hematoma
• Feathery interstitial increased signal pattern on T2 and STIR Wis • Focal muscle enlargement.	• Focal confined mass like collection of blood. • Focal muscle enlargement. • Signal of blood is age dependent.
	

ii. Myotendinous Strain

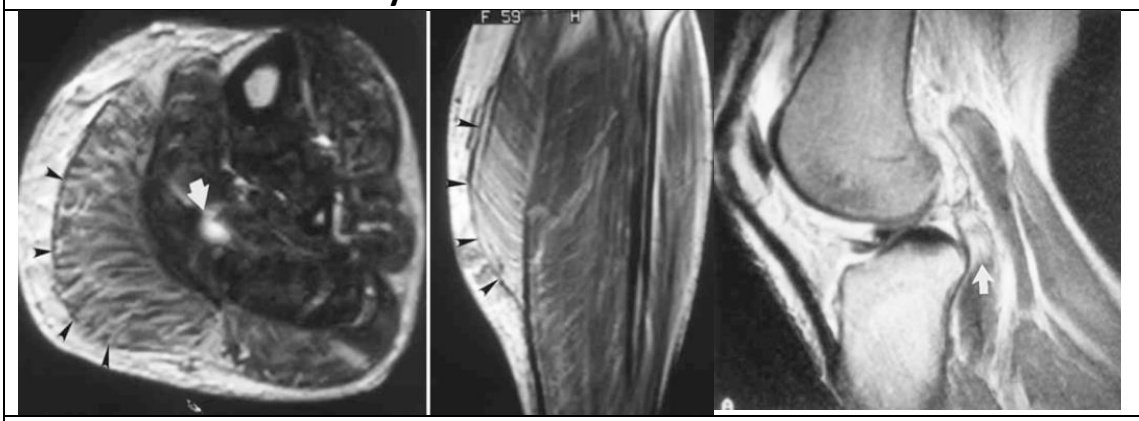
- Myotendinous strains are induced by indirect trauma from excessive stretching.
- Strain injuries affect the myotendinous junction, the weakest point of the musculotendinous unit; as opposed to being a distinct point, is really a 10–12-cm transition zone in which myofibrils contribute to form the tendon

- Delayed-Onset Muscle Soreness (DOMS)
- **1st degree strain:** Interstitial edema and hemorrhage at myotendinous junction and extend into adjacent muscle fascicles, producing feathery appearance on T2/STIR MR images
- **2nd degree strain:** partial tear without retraction + hematoma at the myotendinous junction + perifascial fluid collections
- **3rd degree strain:** complete rupture of the myotendinous unit + Hematoma in gap between retracted fragments.

Delayed-Onset Muscle Soreness (DOMS):

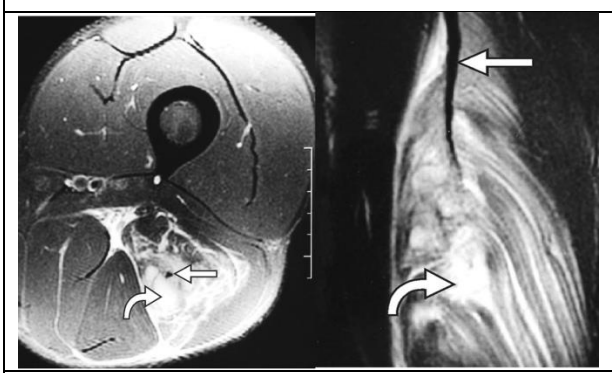
- DOMS is a type of overuse injury that does not become symptomatic until hours or days after the overuse episode,
- DOMS in contrast with a muscle strain or contusion, which usually is immediately painful.
- Mild DOMS is frequently seen in recreational athletes.

Grade I Strain = Feathery

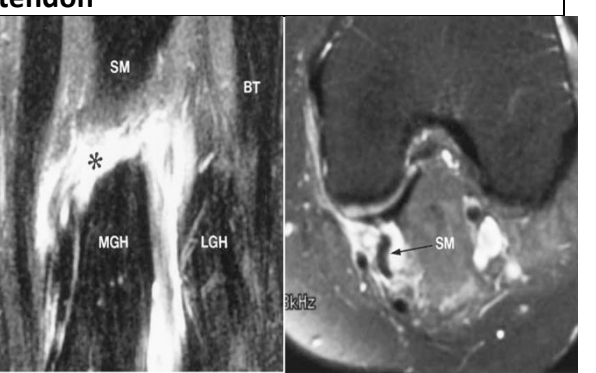


Grade II Strain = Partial tear

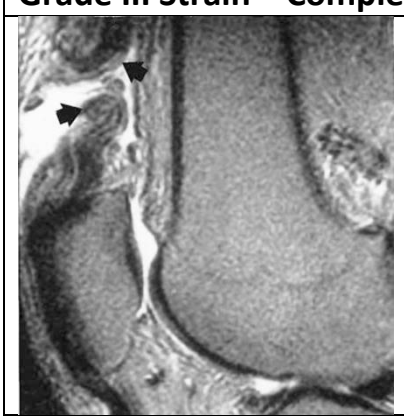
Grade II strain of biceps femoris tendon



Grade II strain of semimembranosus tendon



Grade III Strain = Complete Tear



iii. Tendon Avulsion

- Proximal avulsion involves the conjoint tendon (biceps femoris and semitendinosus muscles).

- Avulsion injury in the adult is usually without an osseous fragment.
- Avulsion injury in adolescents, the apophysis forms the weakest link in the musculotendinous unit due to its incomplete ossification, resulting in osseous avulsion.

- Retracted fibers of the semitendinosus muscle and the long head of the biceps femoris tendon (straight arrow) and Large hematoma (*)

iv. Muscle Herniation

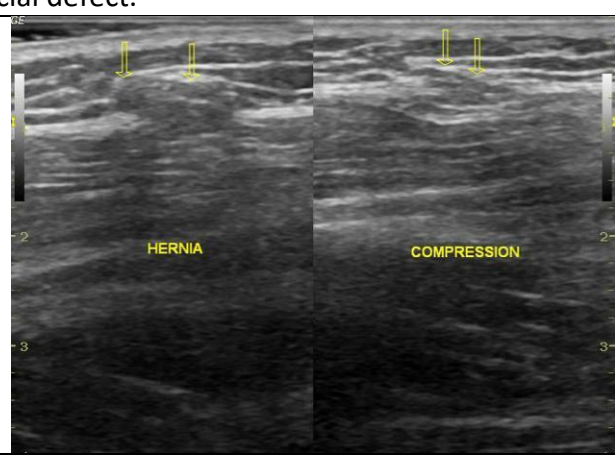
- A focal defect in the muscle fascia with protrusion of muscle through the defect.

US Examination:

- Light pressure examination is preferable, so as not to reduce or efface the herniation.
- Contraction of the involved muscle may reveal or accentuate the lesion.

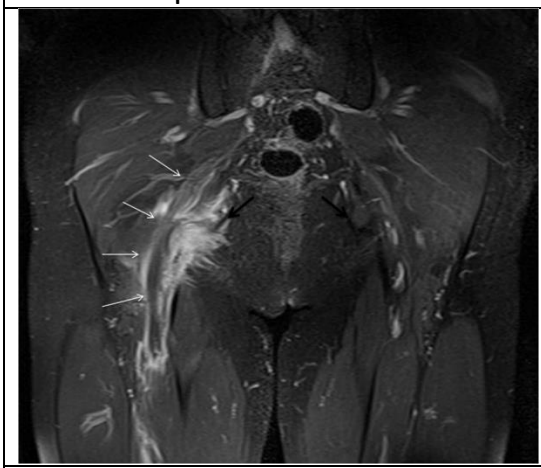
MRI:

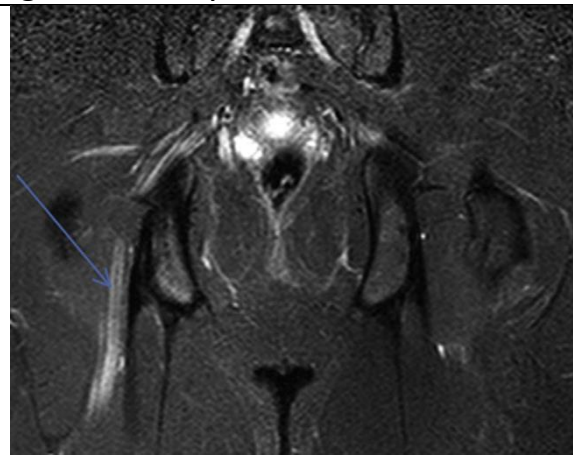
- Normal muscle signal protruding through fascial defect.



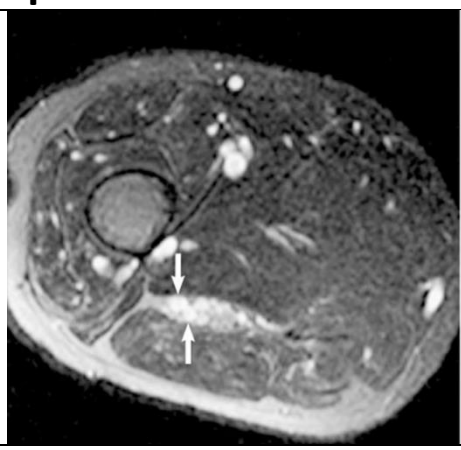
D)Sciatic Neuropathy

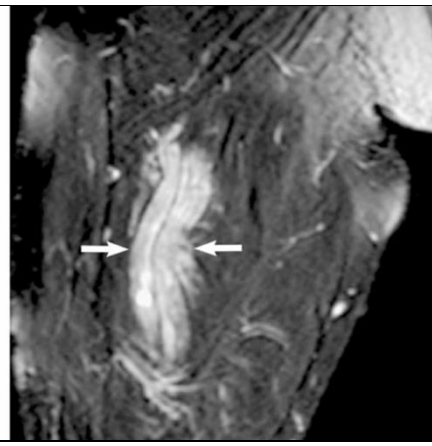
Increased perifascicular and endoneurial signal intensity on STIR



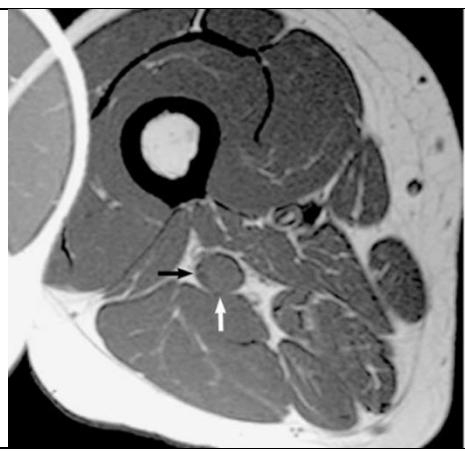


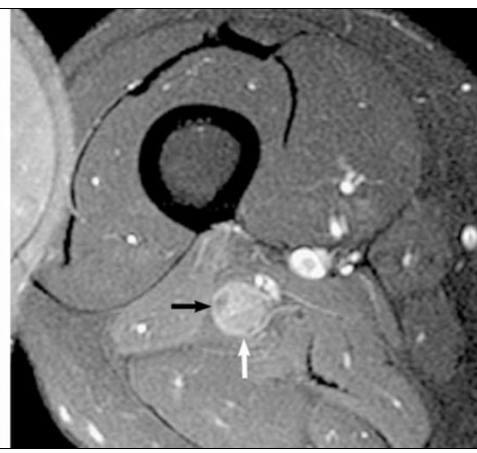
E) Stump Neuroma



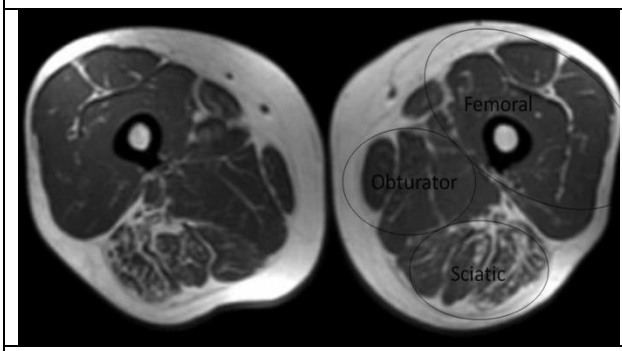


F) Sciatic Nerve Sarcoidosis

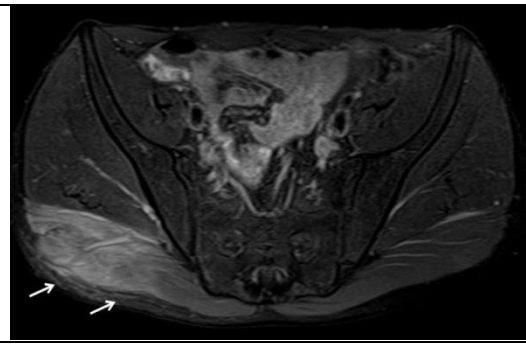




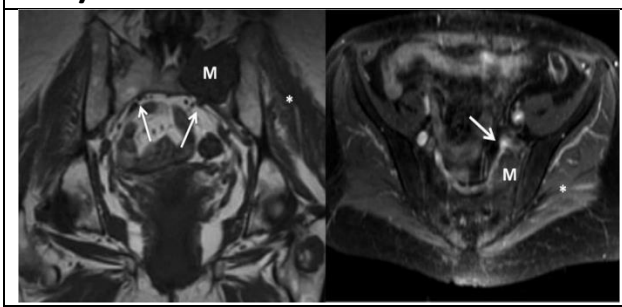
G) Denervation Atrophy of Sciatic nerve



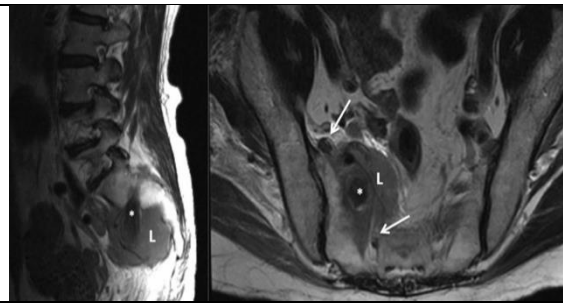
H) Myositis Post-puncture



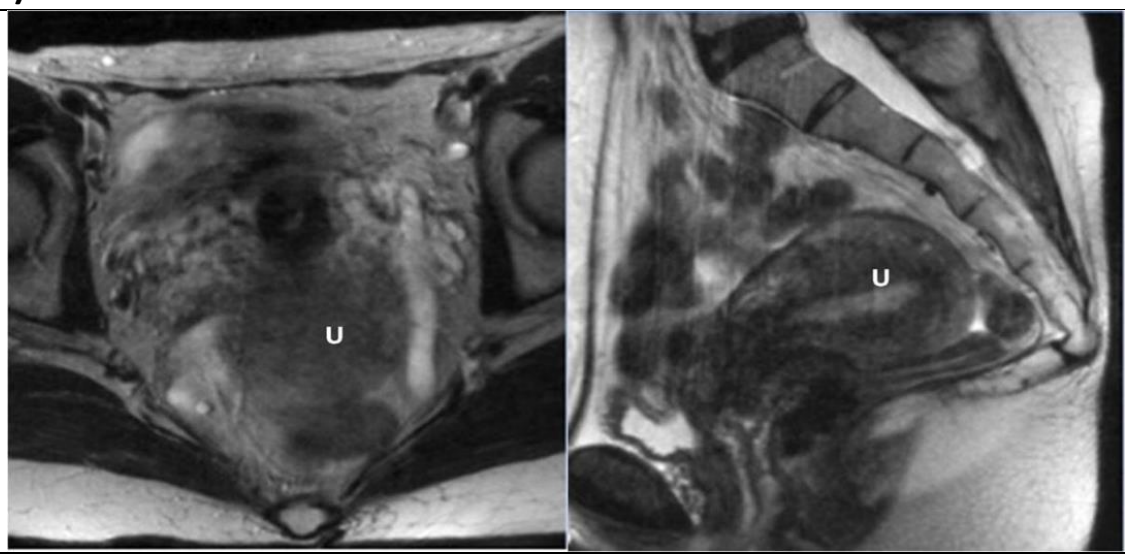
I) Sacral Metastasis



J) Sacral Lymphoma



K) Retroverted Uterus



Hip Pain in Children

Hip pain in children

< 4 years old	4 - 10 years	10 - 16 years
- Transient synovitis - Osteomyelitis/septic artritis - Juvenile idiopathic arthritis - Non-accidental injury - Referred pain from limb	- Transient synovitis - Perthes disease - Osteomyelitis / septic arthritis	- Slipped femoral epiphysis - Avulsion fractures - Osteomyelitis / septic arthritis

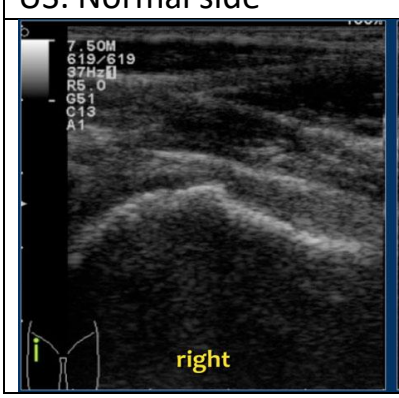
- *uncommon:*
  - *Leukemia*
  - *Eosinophilic granuloma*
  - *Metastases neuroblastoma*
	- *uncommon:*
	  - *Leukemia*
	  - *Ewing*
		- *uncommon:*
		  - *Leukemia*
		  - *Osteoid osteoma*
		  - *Ewing*
		  - *Osteosarcoma*

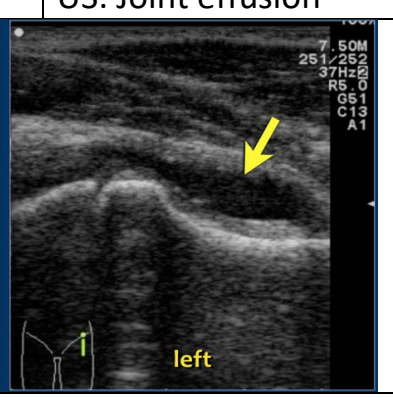
1) Transient Synovitis

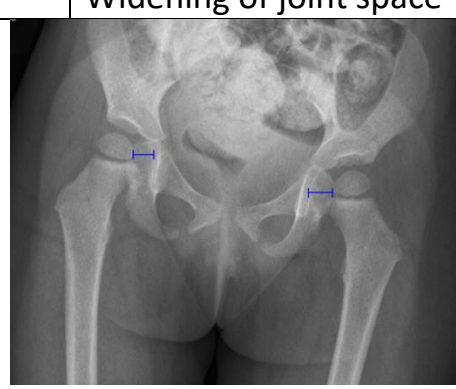
- An aseptic inflammation of the hip, presumably of postviral etiology.
- Most common cause for acute hip pain in a limping child aged 3 to 10 years.
- Clinically: Affected children are only mildly ill or have recently sustained a low grade respiratory tract infection.

- X-ray: Widening of joint space (non-specific sign)
- US: is very sensitive for detecting the presence of hip effusion, but cannot reliably differentiate between transient synovitis and septic arthritis.
- MRI: The presence of marrow signal hyperintensity STIR effectively excludes transient synovitis as cause for hip pain

US: Normal side	US: Joint effusion	Widening of joint space







2) Septic Arthritis

- Osteomyelitis in children is usually due to hematogenous spread. The metaphyses of long bones are the most common sites of infection.

Rout of infection:

- The most common route of infection in a child is hematogenous spread.
- Contiguous spread from adjacent soft tissue infection
- Direct implantation from penetrating trauma are less common
- Osteomyelitis may also spread from the metaphysis to the epiphysis and joint via transphyseal vessels in children under 18 months of age

Causative organism:

- The most common organisms are Staphylococcus aureus and group B Streptococcus

- X-ray: Widening of joint space (non-specific sign)
- US: is very sensitive for detecting the presence of hip effusion, but cannot reliably differentiate between transient synovitis and septic arthritis.
- ***MRI: bone marrow edema and enhancement + Joint effusion***.
    - Very sensitive (88%-100%) and specific (75%-100%) for diagnosis of osteomyelitis.

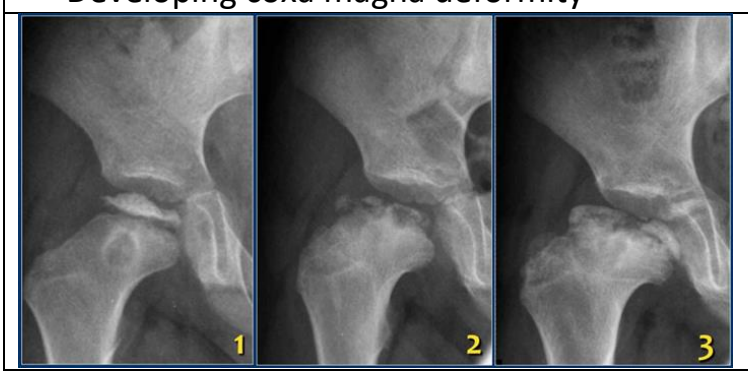
Coronal T1	**Coronal STIR**

3) Perthes disease = Legg-Calvé-Perthes disease

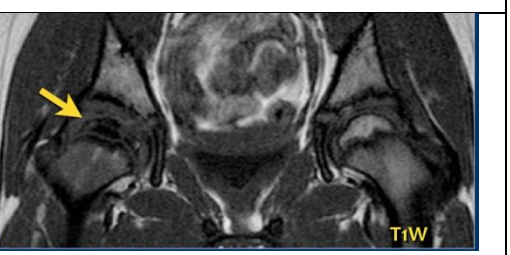
- An idiopathic avascular necrosis of the proximal femoral epiphysis
- More commonly in boys
- Age = between 5 and 8 years of age
- Bilateral 10%; but asymmetrical.

Imaging findings:

- Flattened and sclerotic femoral epiphysis.
- Fragmentation
- Developing coxa magna deformity



T1: loss of high bone marrow signal

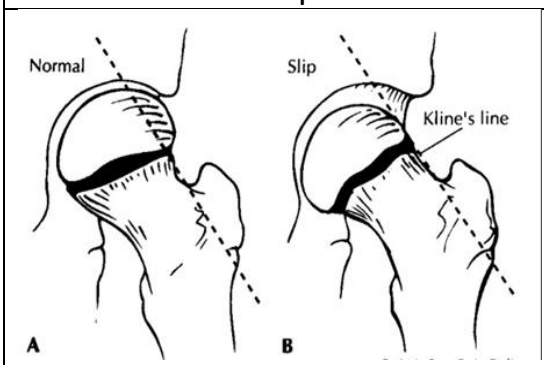


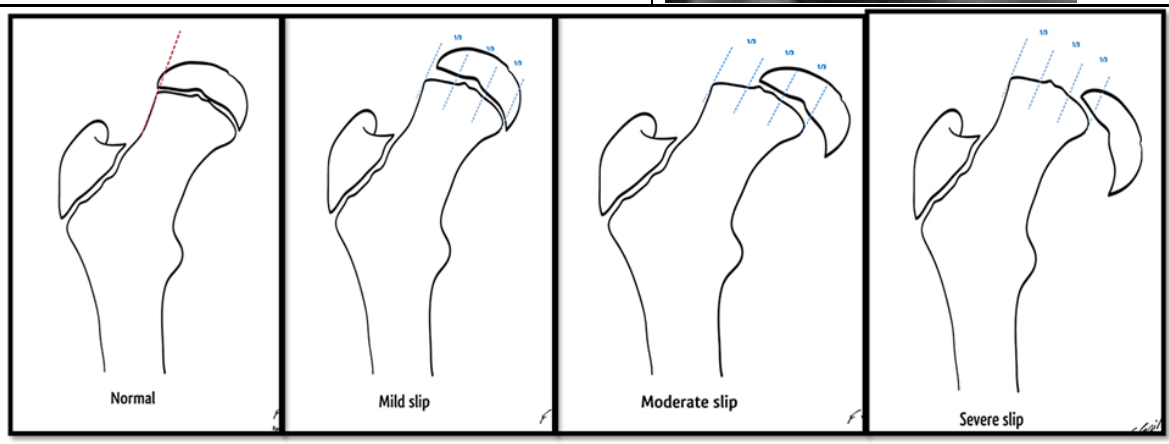
4) Slipped Capital Femoral Epiphysis (SCFE)

- is the most important chronic Salter-Harris type I injury seen.

Klein's line:

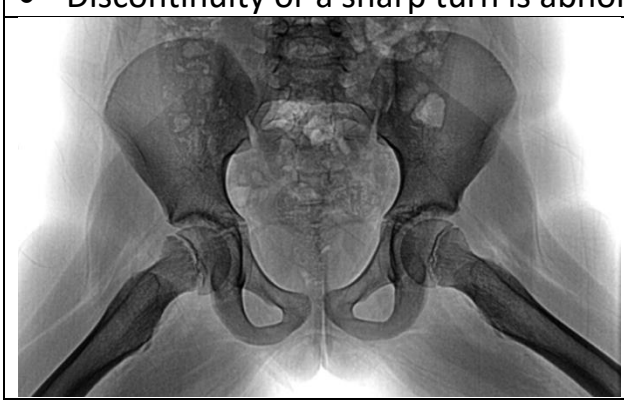
- Line drawn along and parallel to superior aspect of femoral neck.
- Normally: line intersects the epiphysis
- Abnormal: line passes lateral to the epiphysis

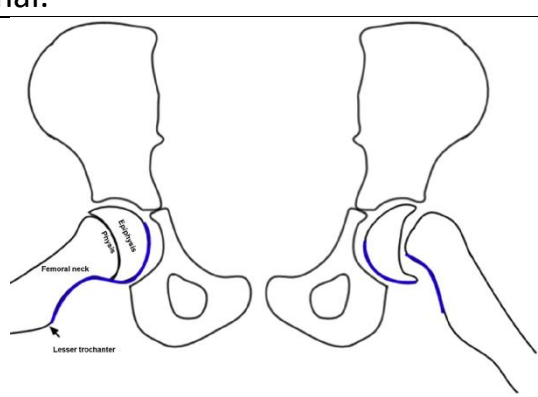




Frog-leg lateral view "The S-sign"

- A curvilinear line drawn on the inferior margin of the proximal femoral head neck junction along the proximal femoral physis.
- Discontinuity or a sharp turn is abnormal.



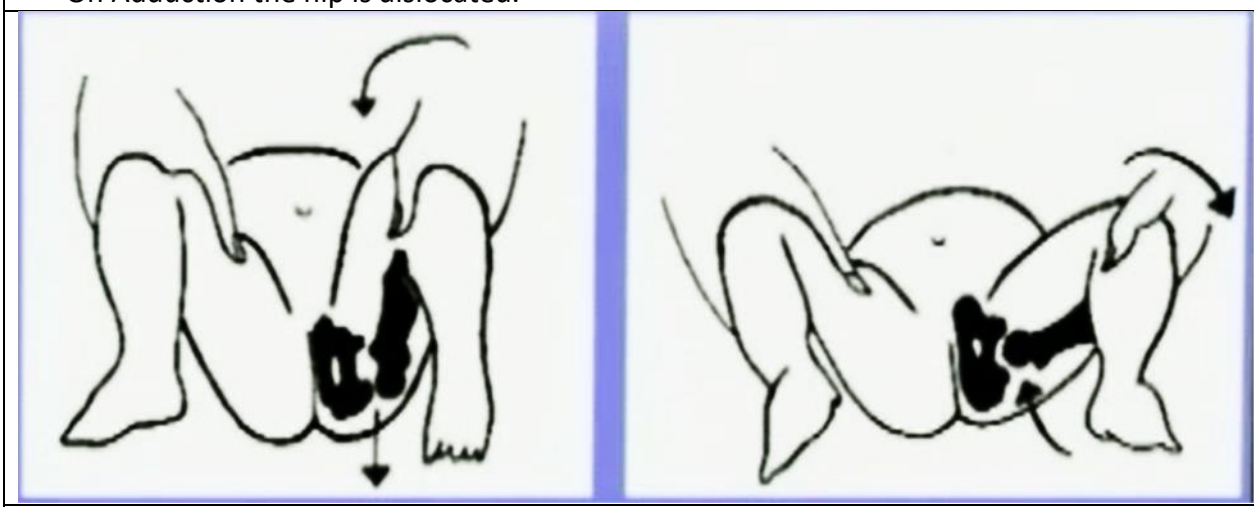


Developmental Dysplasia of Hip (DDH)

- is one of the most common musculoskeletal problems in newborns.
- Girls >> Boys
- LT >> RT
- Risk factor: Breech position.

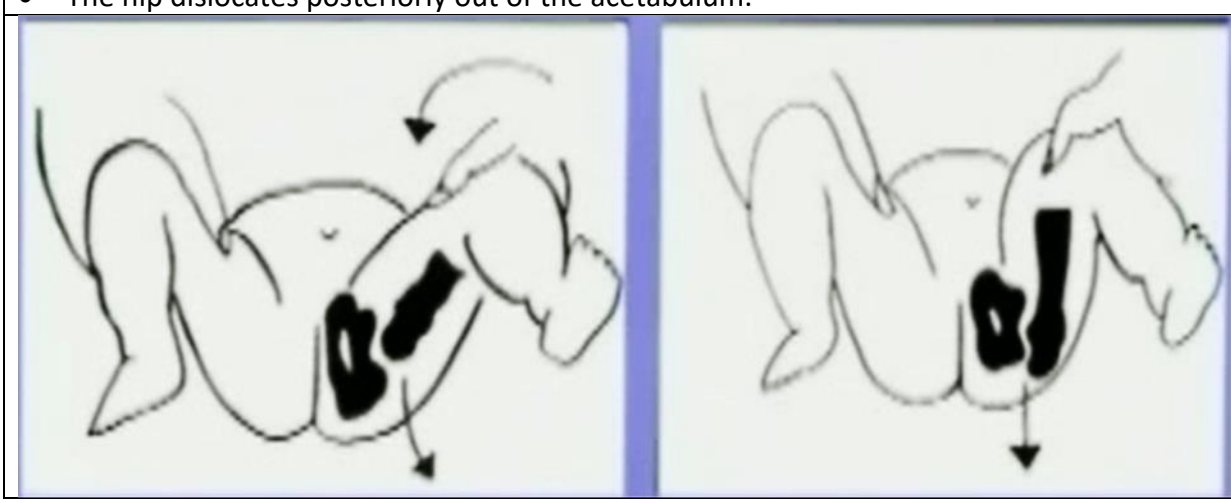
Ortonali Reduction Test:

- On Abduction and external rotation of the hip is gently relocated back into the acetabulum. It typically produces a click.
- On Adduction the hip is dislocated.



Barlow Dislocation Test:

- Gentle adduction and a push on the knee.
- The hip dislocates posteriorly out of the acetabulum.

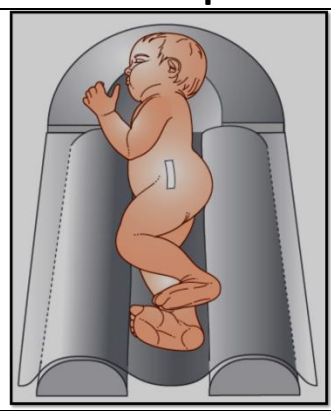


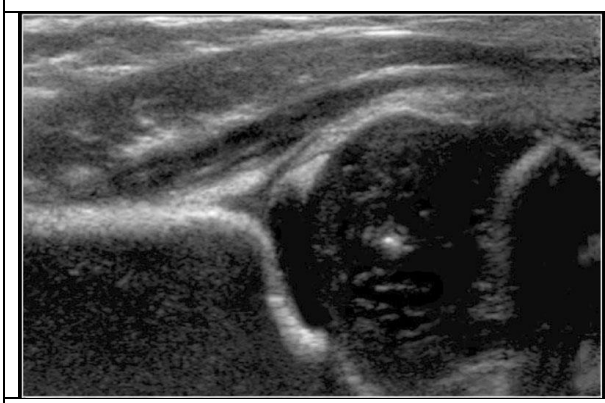
A- Ultrasound

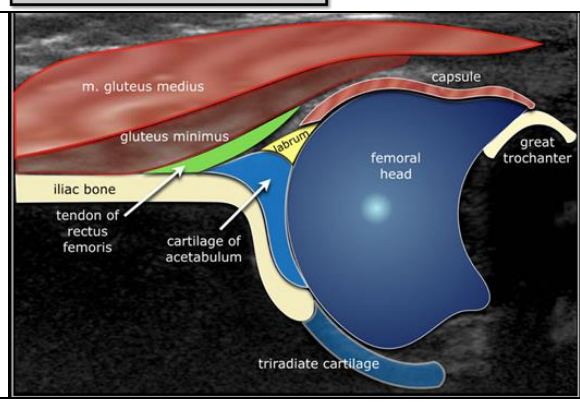
- Ultrasound is the modality of choice
- 4 weeks – 6 months

1) Coronal Longitudinal View: The Graf technique

- The infant is positioned on its side
- The hip in slight flexion.
- The transducer is placed over the greater trochanter

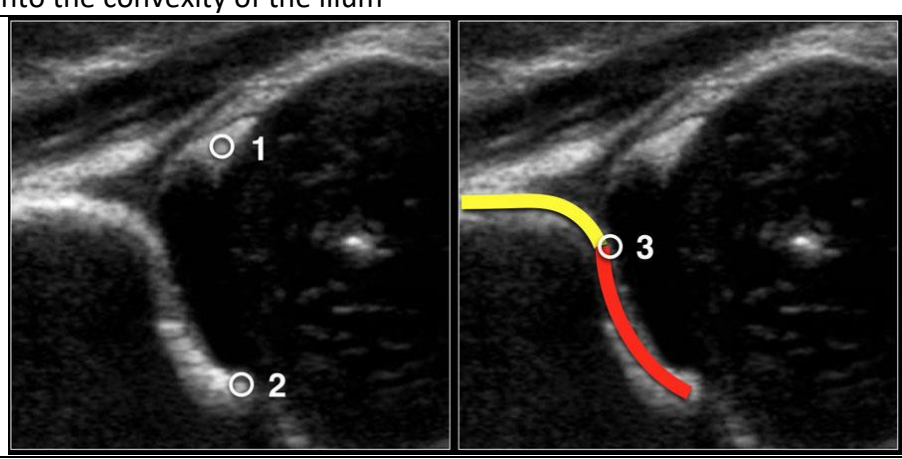




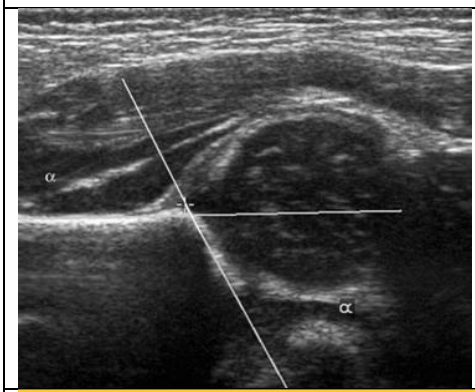


First three points of interest need to be identified in the image:

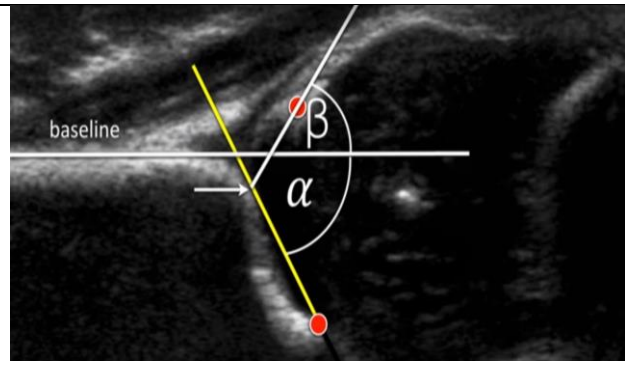
1) Centre of labrum
2) Lower limb of the iliac bone (=Undersurface of the medial border of the acetabulum where the iliac bone meets the triradiate cartilage)
3) Bony rim of acetabulum. When the bony rim is angular this point is easily recognized. When rounded this point is defined as the point where the concavity of the bony acetabular roof changes into the convexity of the ilium



Graf: α Angle
Normal ≥ 60◦



Graf: β Angle = Cartilage roof angle
Normal ≤ 55◦



Developmental Dysplasia of the Hip

α -angle

Type I	α ≥ 60º	
IIa	α 50 - 59º	appropriate for age
Type IIb	α 50 - 59º	inappropriate for age
IIc	α 43 - 49º	
Type D	α 43 - 49º	decentring hip
Type III	α < 43º	eccentric hip
Type IV	α < 43º	inverted labrum

Type	Maturity	Bony roof	Bony angle	Bony rim	Cartilage roof	β-angle	Age
Type I	mature	good	α ≥ 60°	sharp	good coverage femoral head	Ia = β < 55° Ib = β > 55°	All
Type II a+	immature but appropriate for age	adequate	50-59°	blunt	coverage femoral head		< 3 mo
Type II a-	immature and inappropriate for age	deficient	50-59°	rounded	coverage femoral head		< 3 mo
Type II b	delay in development	deficient	50-59°	rounded	coverage femoral head		> 3 mo
Type II c	stable or unstable	severely deficient	43-49°	rounded / flat	still coverage femoral head	β < 77°	All
Type D	decentring hip	severely deficient	43-49°	rounded / flat	displaced	β > 77°	All
Type III	eccentric hip	poor	< 43°	flat	labrum pressed upwards		All
Type IV	eccentric hip	poor	< 43°	flat	labrum pressed downwards		All

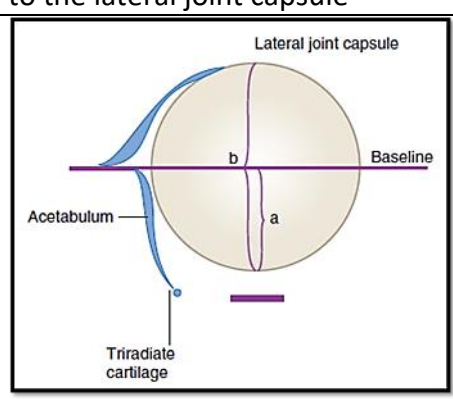
2) Coronal Longitudinal View
Terjesen Femoral Head Coverage

The femoral head coverage (FHC) = a/b × 100
a = distance from the medial wall of the acetabulum to the level of the lateral bony rim
b = distance from the medial wall of the acetabulum to the lateral joint capsule

Box 10.1 Terjesen femoral head coverage

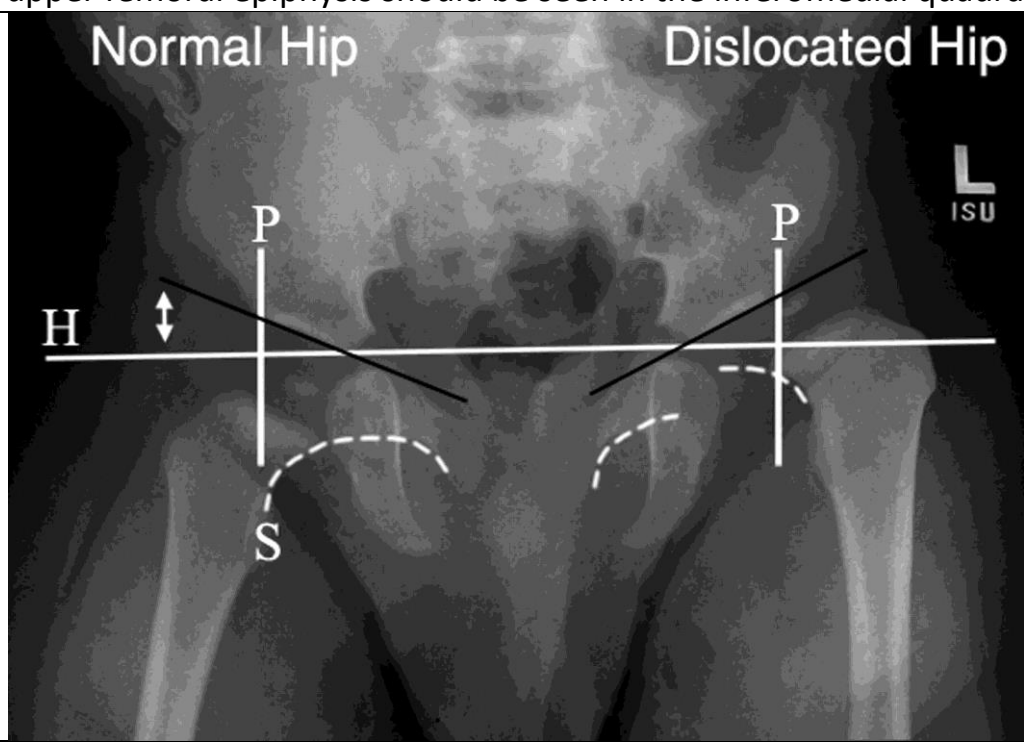
Femoral head coverage:

> 50%	Normal
49–40%	Possible dysplasia in newborns
49–40%	Dysplasia in infants greater than 4 months
39–10%	Subluxation
< 10%	Dislocation



B- Plain Radiograph

- The Hilgenreiner line is a line drawn horizontally through the inferior aspect of both triradiate cartilages.
- Perkin line is a line drawn perpendicular to Hilgenreiner line, intersecting the lateral most aspect of the acetabular roof.
- The angle is formed by Hilgenreiner line and a second line which extends along the acetabular roofs. (Normal range = 33º to 38º)
- Shenton line is an imaginary curved line drawn along the inferior border of the superior pubic ramus (superior border of the obturator foramen) and along the inferomedial border of the neck of femur.
- The upper femoral epiphysis should be seen in the inferomedial quadrant



Proximal Focal Femoral Deficiency (PFFD)

is a congenital partial absence of the proximal end of the femur with shortening of the entire limb.

❖ Aitken Classification:

Class A

- Least severe type
- Femoral head is present and attached to the shaft by the femoral neck.
- the femur is shortened (as in all types), and a coxa vara deformity is present
- A cartilaginous neck is not seen on early radiognaphs but later ossifies.
- Occasionally, the cartilaginous connection between the neck and the shaft forms a sub trochantenic pseudarthrosis.

Class B

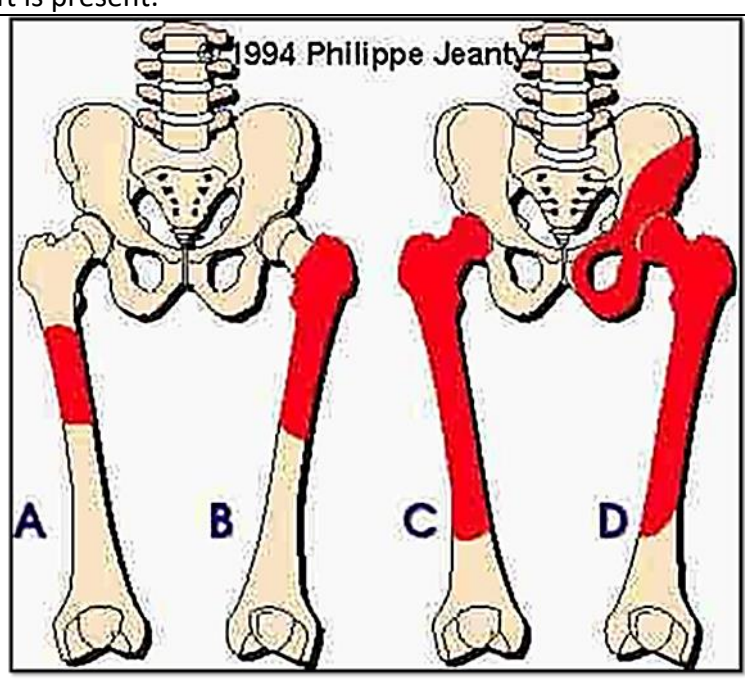
- The acetabulum is "adequate" on moderately dysplastic and contains the femoral head.
- At maturity, no osseous connection is seen between the femoral head and the shaft.
- The femoral segment is short and usually has a bulbous bony tuft.

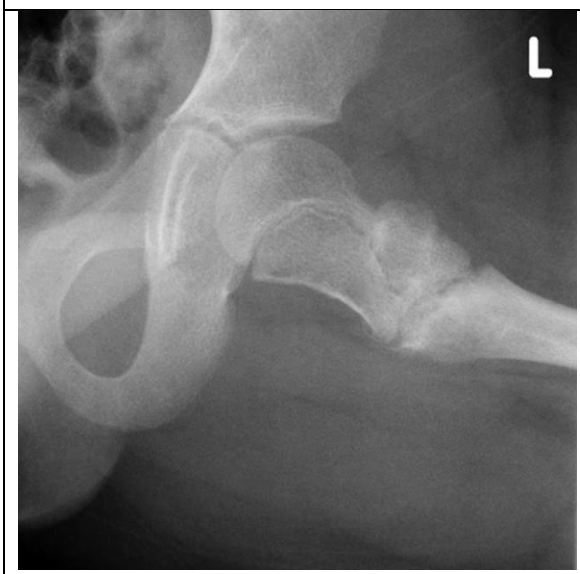
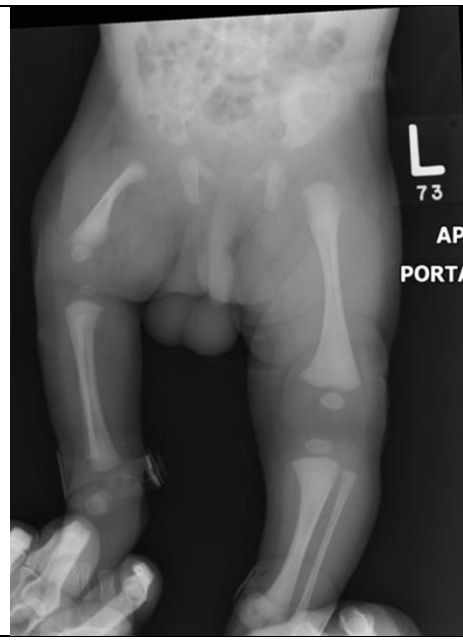
Class C

- The acetabulum is severely dysplastic in this form.
- The femoral head is absent or is very small and not attached to the femoral shaft.
- The shortened femoral segment has a tapered proximal end.

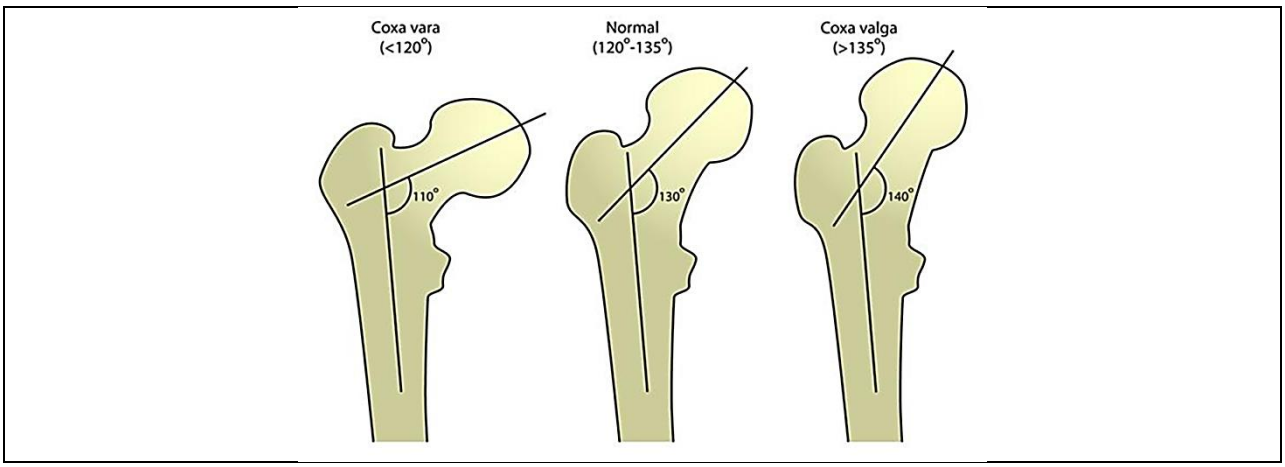
Class D

- This is the most severe form, with absence of the acetabulum and proximal femur.
- No proximal tuft is present.



Class A	Class B
	
Class C	**Class D**

Coxa

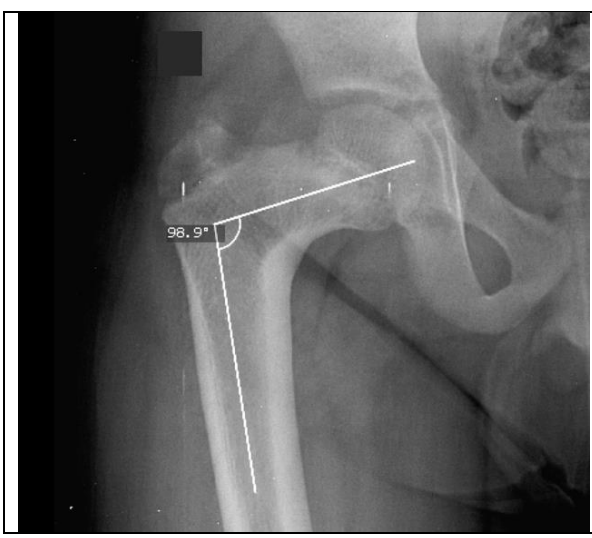


A) Coxa Vara

- Deformity of the hip where the angle formed between the head and neck of the femur and its shaft (Mikulicz angle) is < 120 degrees

Classification

- Idiopathic:
  - Congenital: mild or severe coxa vara, with associated congenital anomalies: see associations
  - Developmental: progressive, usually appearing between the ages of two and six years, with characteristic roentgenologic features
- Rachitic: usually associated with active rickets
- Adolescent: secondary to slipped capital femoral epiphysis
- Traumatic: usually following fracture of the femoral neck (rare in children)
- Inflammatory: secondary to tuberculosis or other infection
- Secondary to other underlying bone diseases such as:
  - Osteogenesis imperfecta
  - Cretinism
  - Dyschondroplasia(s)
  - Paget's disease
  - Osteoporosis
- Capital coxa vara: occasionally seen in severe osteoarthritis and legg-perthes' disease



B) Coxa Valga

- A deformity of the hip where there is an increased angle between the femoral neck and femoral shaft >140^0
- Coxa valga is often associated with shallow acetabular angles and femoral head subluxation.

<u>Aetiology</u>:

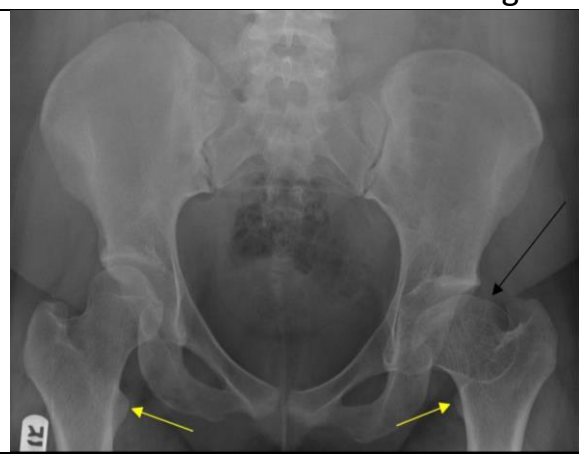
- Bilateral
  - Neuromuscular disorders, e.g. Cerebral palsy
  - Often have concurrent femoral anteversion
  - Skeletal dysplasias, e.g. Turner syndrome, mucopolysaccharidoses
- Unilateral
  - Trauma causing growth plate arrest

C) Coxa Magna

- Asymmetrical, circumferential enlargement and deformation of the femoral head and neck.
- Enlargement with asymmetry >10% in size is a reasonable cut-off for diagnosis

Aetiology

- **Legg-Calve-Perthes disease**
- Transient synovitis of the hip
- Developmental dysplasia of hip
- Trauma
- Septic arthritis / osteomyelitis
- Juvenile rheumatoid arthritis
- Chronic slipped capital femoral epiphysis



D) Coxa Plana

- Coxa plana is flattening of the femoral head epiphysis

Aetiology

- **Legg-Calvé-Perthes disease**
- Haemophilic haemarthrosis
- Gaucher disease
- Hypothyroidism
- Spondyloepiphyseal dysplasia
- Multiple epiphyseal dysplasia
- Haemoglobinopathies, e.g. Sickle cell anaemia, thalassemia

E) Protrusio Acetabuli

- intrapelvic displacement of the acetabulum and femoral head, so that the femoral head projects medial to the ischioilial line.

Primary

- Characterised by progressive protrusio in middle aged women.
- The condition may be associated with osteoarthritis and may be familial.

Secondary

- Paget disease
- Psoriatic arthropathy
- Rheumatoid arthritis
- Ankylosing spondylitis
- Osteomalacia / Rickets
- Osteogenesis imperfecta
- Marfan syndrome
- Trauma
- Haemophilia (in advanced arthropathy)

Marfan Syndrome	RA

Femoral Head Avascular Necrosis

Aetiology

- Traumatic (secondary to the neck of femur fractures)
- Non-traumatic:
  - Chronic corticosteroid therapy
  - Alcoholism
  - Smoking
  - Systemic lupus erythematosus (sle)
  - Hyperlipidaemias
  - Hiv
  - Haemoglobinopathies
  - Chronic renal failure
  - Diabetes mellitus
  - Pregnancy-related

❖ Ficat and Arlet Classification

Stage 0

- Plain radiograph: normal
- MRI: normal
- Clinical symptoms: nil

Stage I

- Plain radiograph: normal or minor osteopenia
- MRI: oedema
- Bone scan: increased uptake
- Clinical symptoms: pain typically in the groin

Stage II

- Plain radiograph: mixed osteopenia and/or sclerosis and/or subchondral cysts
- MRI: geographic defect
- Bone scan: increased uptake
- Clinical symptoms: pain and stiffness

Stage III

- Plain radiograph: subchondral lucency (crescent sign) and eventual cortical collapse
- MRI: same as plain radiograph
- Clinical symptoms: pain and stiffness+/- radiation to knee and limp

Stage IV

- Plain radiograph: end-stage with evidence of secondary degenerative change
- MRI: same as plain radiograph
- Clinical symptoms: pain and limp

Radiological Findings:

- Osteoporosis + Sclerosis + Cystic changes
- Crescent sign
- Loss of spherical weight bearing dome
- Partial collapse
- Secondary osteoarthritis.

MRI Findings:

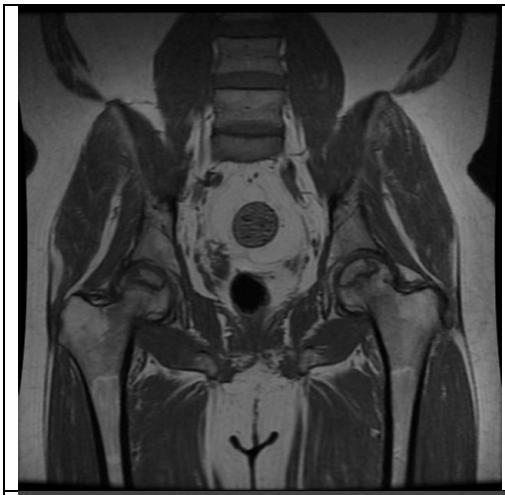
- Earliest sign = Bone marrow edema = Non-specific sign.
- Well defined geographical area in antero-superior portion of femoral head.
- T1: Single dark band = Low signal rim surrounding avascular area.
- T2: Double line sign = 2 concentric high inner and low outer signal bands.
- Late AVN = Fibrosis of subchondral bone (Low signal on T1 & T2) + Femoral head collapse

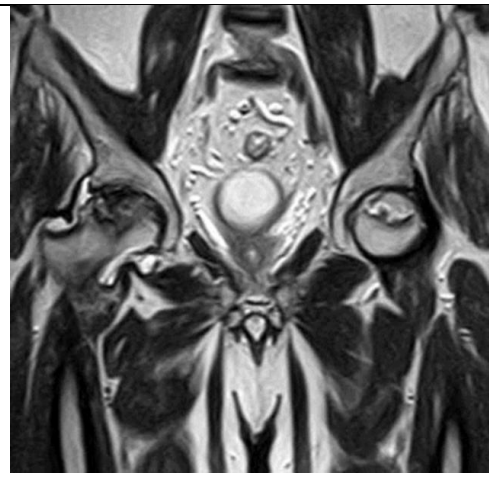
Mitchell Classification of the central Avascular segment:

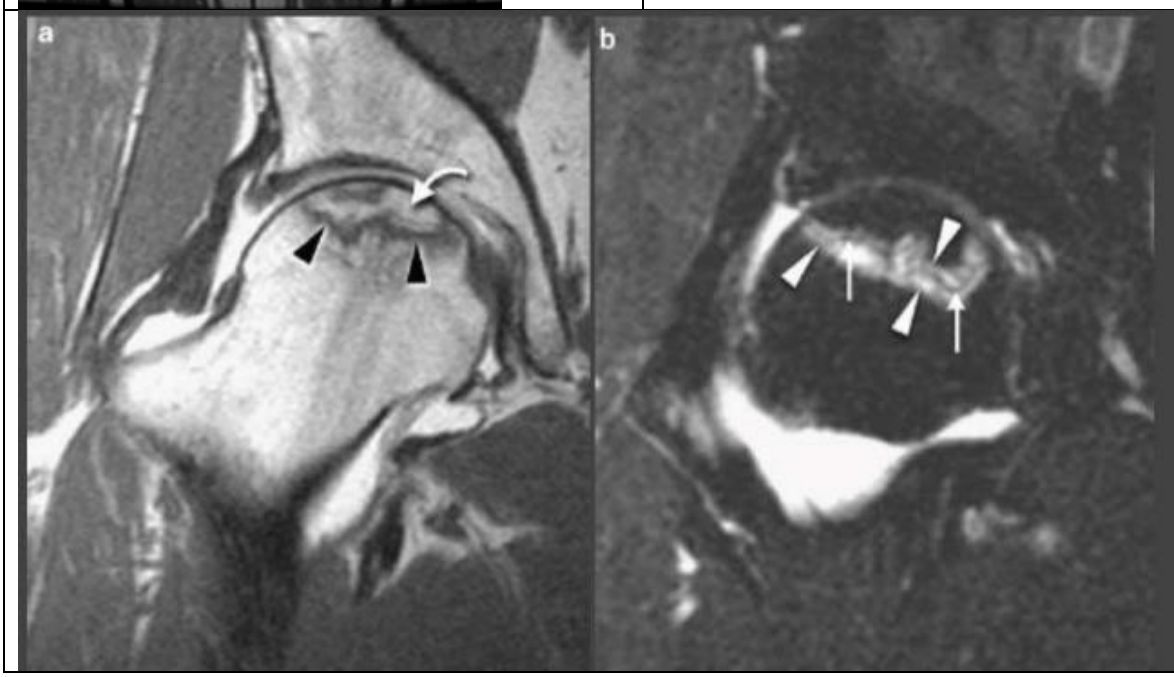
- Class A = Fat = High signal T1 + Intermediate signal T2
- Class B = Blood = High signal T1 & T2
- Class C = Fluid = Low signal T1 + high signal T2
- Class D = Fibrous = Low signal T1 & T2

Bone Scan:

- Photopenic area = cold spot






a
b

Transient Osteoporosis

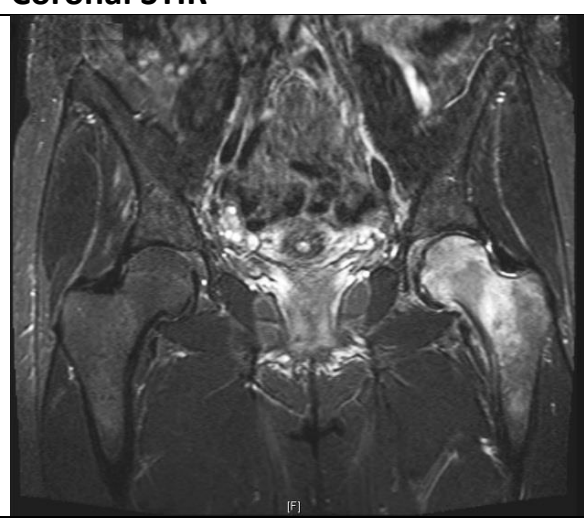
- Self-limiting clinical entity of unknown cause, although almost certainly a vascular basis and possible overactivity of the sympathetic system exists.
- Typically transient osteoporosis of the hip resolves spontaneously within 6-8 months after protected weight-bearing and pain control.
- Middle age men (40-55 year olds)
- M:F ratio 3:1.

Plain Radiograph

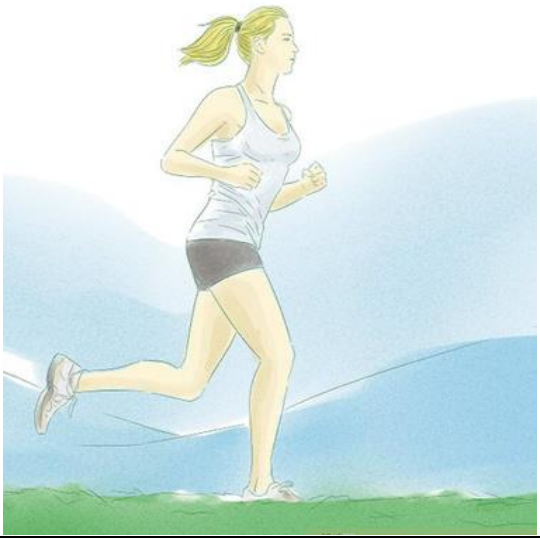
- Typically plain radiographs are normal initially

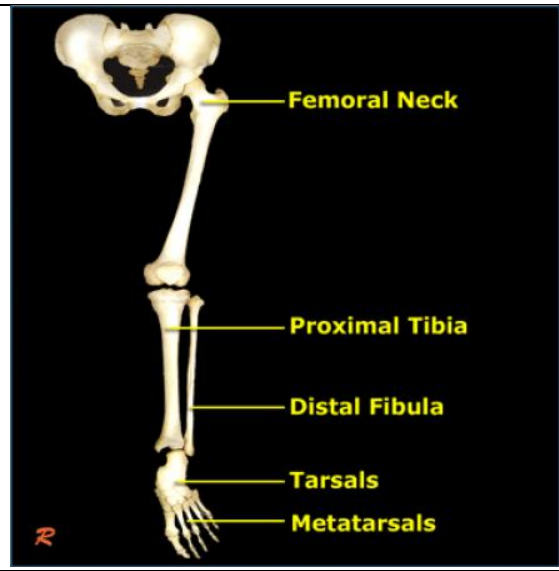
MRI

- Bone marrow oedema pattern involving the femoral head, neck, and even intertrochanteric region

Coronal T1	Coronal STIR
	

Common Stress Injury / Fracture in Runners





- Common cause of pain in athletes
- Most frequently encountered in long-distance runners
- Stress injuries occur due to excess stress applied to normal bones

Radiographs

- Occult in the early stages of injury
- Periosteal reaction
- Lucent fracture line and endosteal sclerosis

Bone Scintigraphy

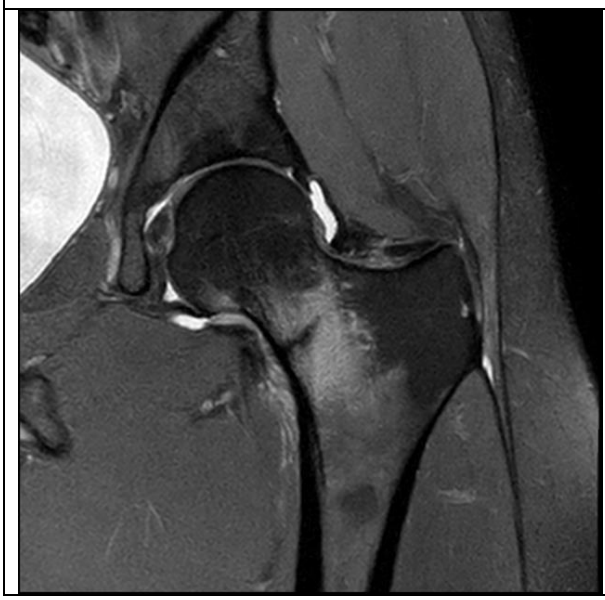
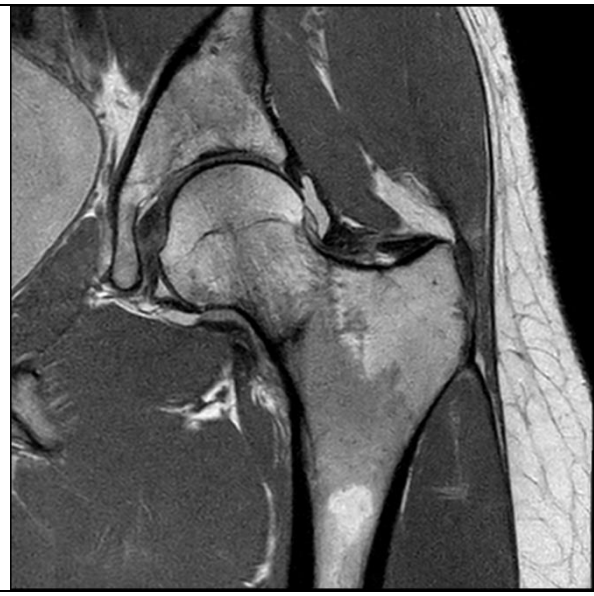
- A typical linear band of increased radiotracer uptake on delayed images

MRI

- Grade 1: subtle periosseous edema that may be seen only on STIR images.
- Grade 2: subcortical bone marrow edema and periosseous soft-tissue edema on T2- FS images, without corresponding hypointense signal on T1- images.
- Grade 3: extensive periosseous edema and bone marrow edema, seen on both T2- and T1-weighted images.
- Grade 4: stress fracture with a discrete low signal fracture line visible at MR imaging

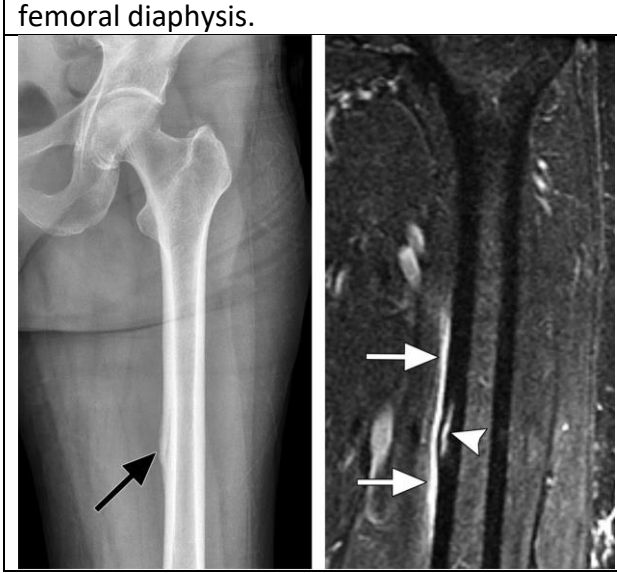
1) Femoral Neck Stress Injury / Fracture

At the medial aspect of the femoral neck

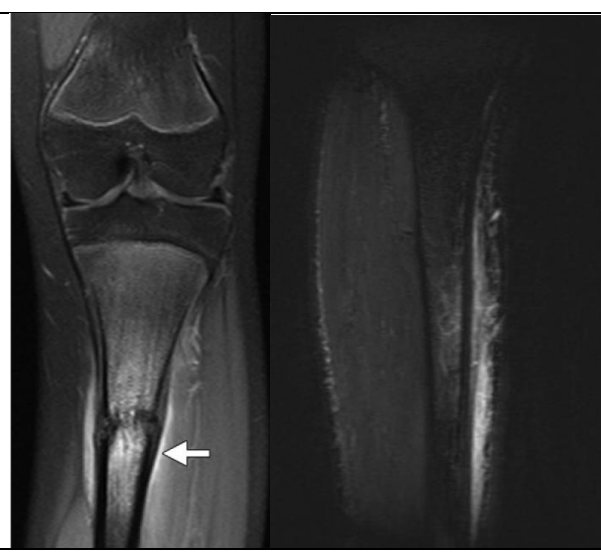
Coronal STIR	Coronal T1
	

2) Adductor Insertion Avulsion Syndrome (Thigh Splints)

Adductor muscles insertion site along the posterior margin of the proximal and mid femoral diaphysis.



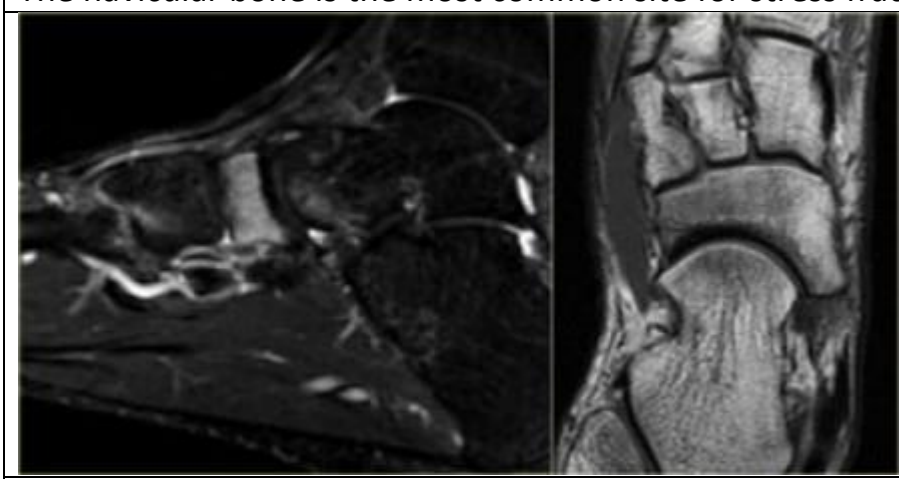
3) Medial Tibial Stress Syndrome (Shin Splints)



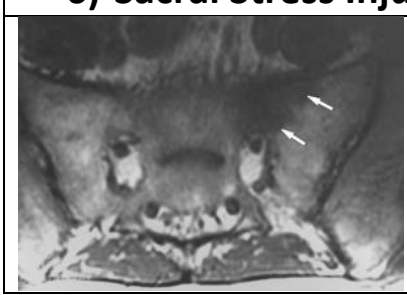
4) Metatarsal Stress Injury / Fracture

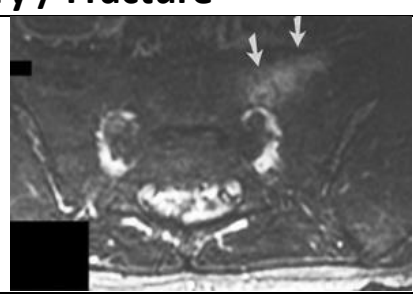
5) Tarsal bones Stress Injury / Fracture

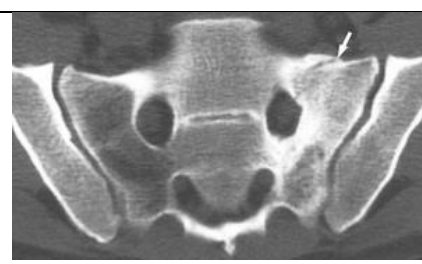
The navicular bone is the most common site for stress fractures of the tarsus.



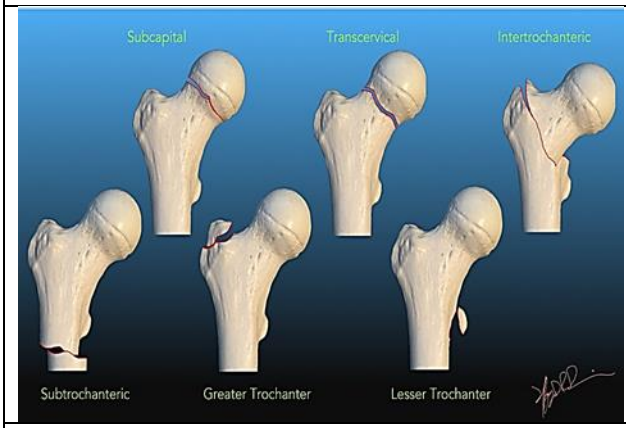
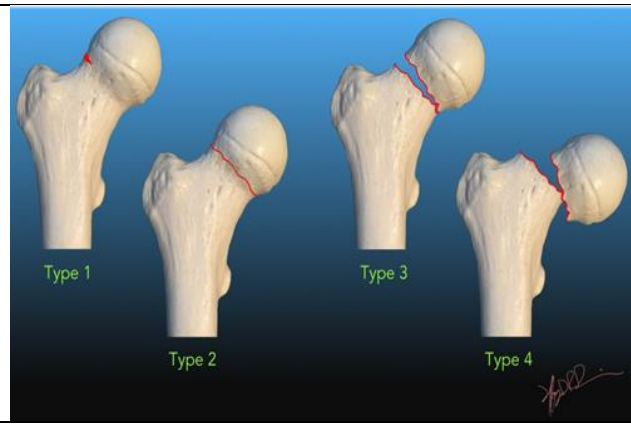
6) Sacral Stress Injury / Fracture







Femoral Neck Fractures

Femoral Neck Fracture Nomenclature	Garden Classification
	

- Predisposing factors: aging, osteoporosis and osteomalacia
- In the elderly (90%): Fall, frequently a minor fall such as from standing position
- In younger individuals: high velocity, high impact trauma
- Hip fractures are associated with a substantial mortality
- 15-20% dying within one year of the fracture

Types:

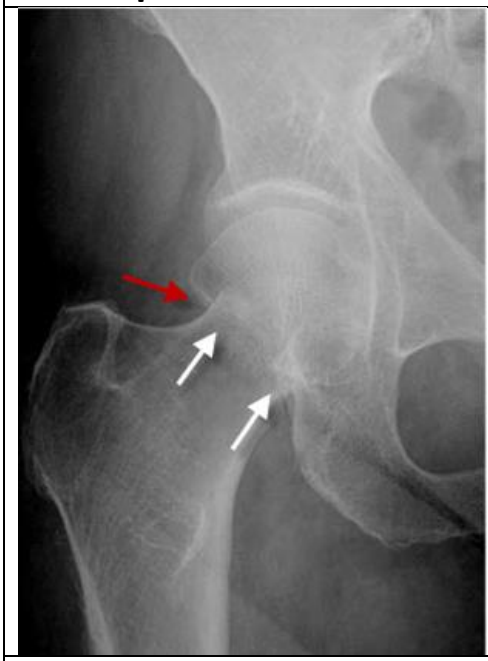
a) Intracapsular fractures

i. Subcapital: femoral head/neck junction
ii. Transcervical: midportion of femoral neck
iii. Basicervical: base of femoral neck

b) Extracapsular fractures

i. Intertrochanteric: fractures that span the intertrochanteric line
ii. Subtrochanteric: fractures below the trochanters
iii. Isolated fractures of greater trochanter
iv. Isolated fractures of lesser trochanter

Classification	Simplified classification	Description	Notes
Type 1	Nondisplaced	Incomplete, nondisplaced, including valgus impacted fractures	~7% AVN. Typically treated with percutaneous fixation
Type 2		Complete, nondisplaced	
Type 3	Displaced	Complete, incompletely displaced	~ 37% AVN. Typically treated with ORIF or arthroplasty
Type 4		Complete, completely displaced	

Sub-capital Fracture	Basicervical Fracture
	
Intertrochanteric Fracture	**Subtrochanteric Fracture**

Pelvic Fractures

Mechanism of Injury:

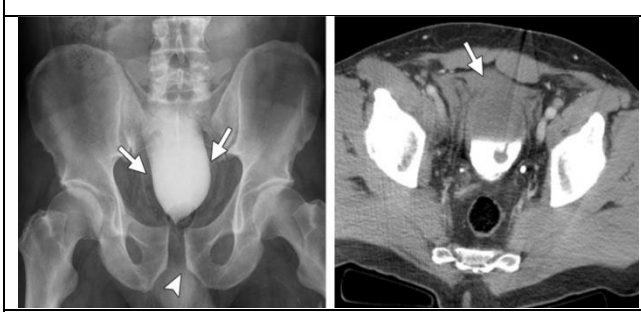
i. AP compression: results from head-on motor vehicle collisions in which the patient is a passenger. The injuries also result when a motorcycle accident occurs.
ii. Lateral compression: results from side-impact motor vehicle accident.
iii. Vertical shearing: typically occur as a result of a fall from a height
iv. Combined

1) AP Compression Injury

Type	Characteristics
Type I	Pubic diastasis <2.5 cm
Type II	Pubic diastasis >2.5 cm Anterior SI joint disruption
Type III	Pubic diastasis >2.5 cm Posterior SI joint disruption

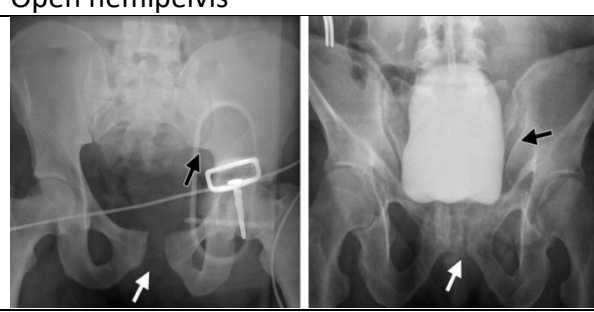
AP Compression type 1

Pubic symphysis diastasis of 1.5 cm (arrowhead)
No posterior pelvic ring injury
Extraperitoneal pelvic hematoma (arrow)



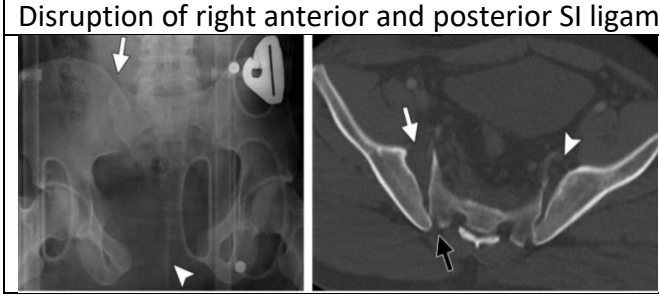
AP Compression type 2

Pubic symphysis diastasis >2.5cm (white arrow
Widening of the left SI joint (black arrow)
Broadening of the left iliac wing.
Open hemipelvis



AP Compression type 3

Pubic symphysis diastasis >2.5cm
Widening of right SI joint + Mild widening of left SI joint
Disruption of right anterior and posterior SI ligaments + left anterior SI ligament



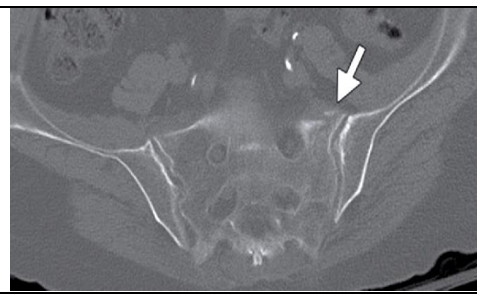
2) Lateral Compression Injury

Type	Characteristics
Type I	Ipsilateral sacral buckle fractures, Ipsilateral horizontal pubic rami fractures (or disruption of symphysis with overlapping pubic bones)
Type II	Type I + ipsilateral iliac wing fracture or posterior SI joint disruption
Type II (windswept pelvis)	Ipsilateral hemipelvis sustains either a type I or type II injury. Contralateral vertical pubic rami fractures or disruption of the sacrotuberous and/or sacrospinous ligaments may occur.

Lateral Compression Type 1

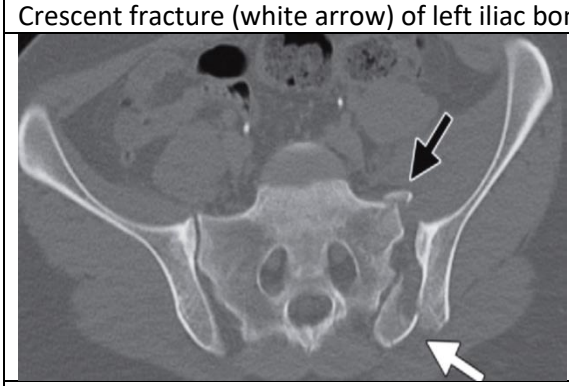
Left inferior pubic ramus fracture

Buckle fracture of the left anterior sacrum

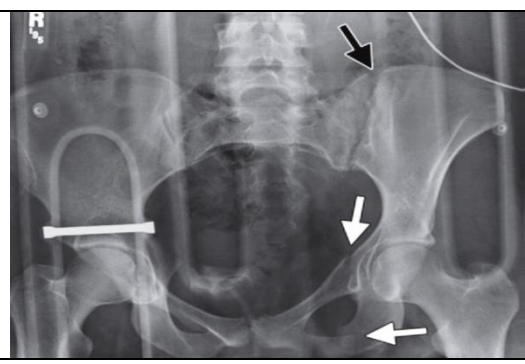


Lateral Compression Type 2

Fracture of the anterior sacrum (black arrow)
Widening of SI joint
Crescent fracture (white arrow) of left iliac bone

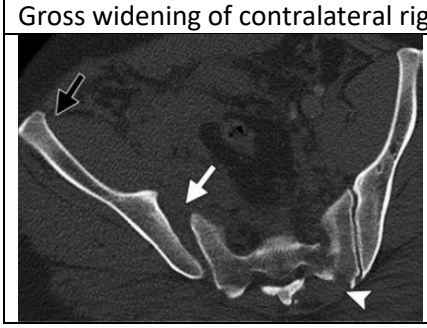


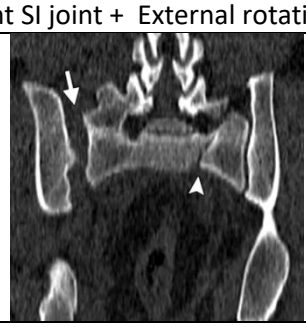
Left-sided overlapping superior and inferior pubic rami fractures (white arrows)

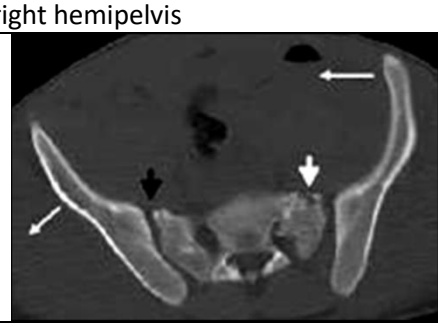


Lateral Compression Type 3 = "windswept pelvis" injury

Compression fracture of left sacrum + Medialized left hemipelvis
Gross widening of contralateral right SI joint + External rotation of right hemipelvis



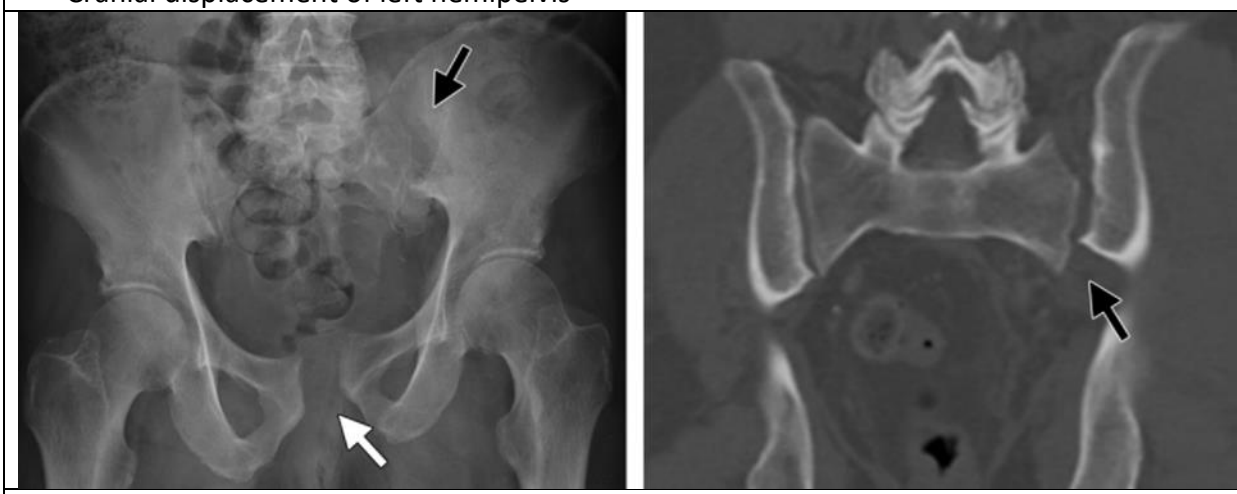




3) Vertical Shear Injury

- Vertically oriented fractures of the pubic rami occur.
- Posteriorly, the ipsilateral SI joint (or occasionally the contralateral SI joint) and its associated ligaments are disrupted.
- The affected hemipelvis is displaced in a cranial direction.
- Complete disruption of posterior ligaments yields a rotationally and vertically unstable pelvis

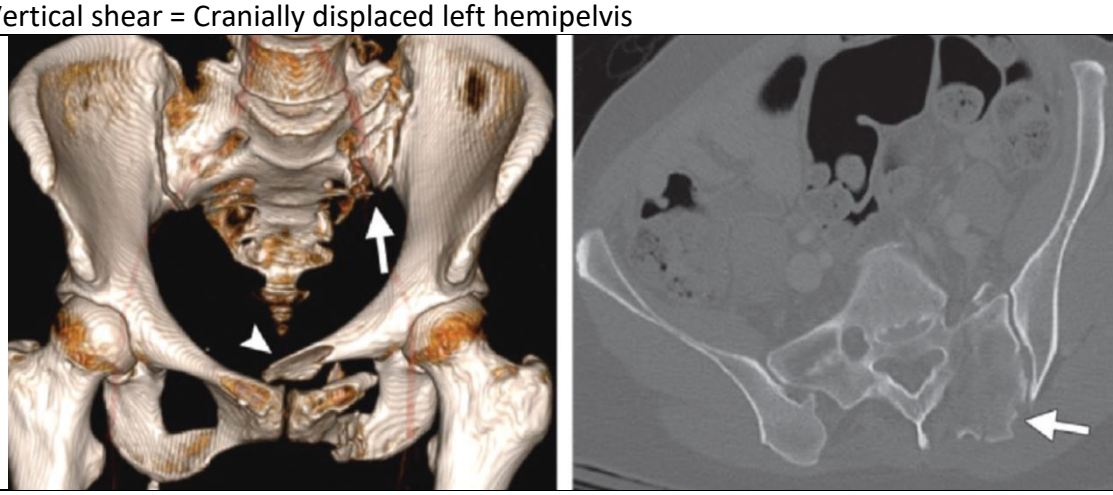
- Widening of pubic symphysis (white arrow)
- Widening of left SI joint (black arrow)
- Cranial displacement of left hemipelvis



4) Complex Injury

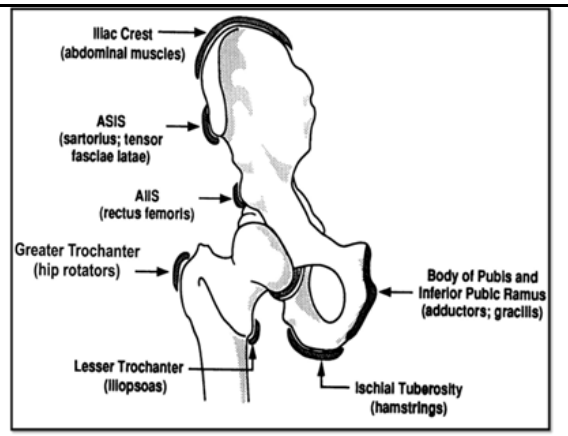
- The forces applied to the pelvis may not conform to the primary vectors described for other types of injuries.
- Complex injuries involve more than 1 pattern of injury.

- Lateral compression: overlapping horizontal fractures of the pubic rami (arrowhead) + sacral fracture (arrow)
- Vertical shear = Cranially displaced left hemipelvis



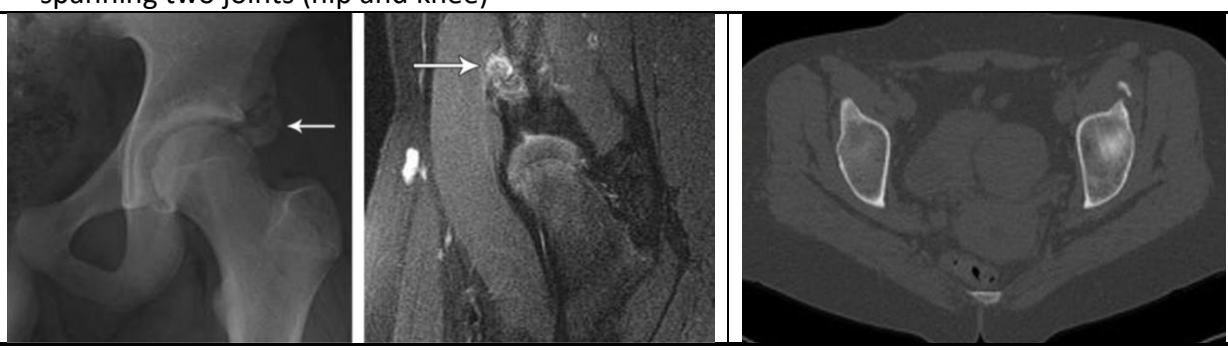
Pelvic Avulsion Fractures

1) Ischial tuberosity (hamstrings),
2) Anterior superior iliac spine (sartorius and tensor fascia lata),
3) Anterior inferior iliac spine (rectus femoris),
4) Symphysis pubis and inferior pubic ramus (long adductor, short adductor, and gracilis),
5) Iliac crest (abdominal musculature),
6) Greater trochanter (gluteus medius and minimus, internal obturator, gemellus, and piriformis)
7) Lesser trochanter (iliopsoas).

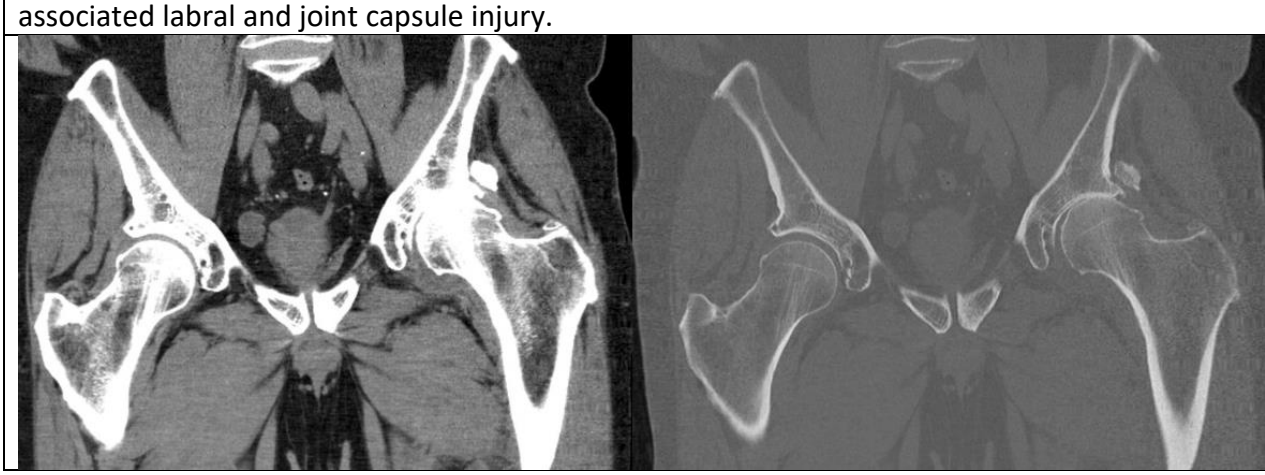


1) AIIS Avulsion

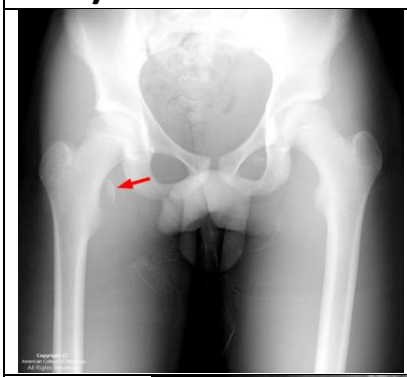
- The AIIS is the proximal attachment of the rectus femoris muscle and is the most proximal aspect of the entire extensor mechanism of the knee.
- The rectus femoris muscle is at higher risk of injury than other muscles as a result of spanning two joints (hip and knee)

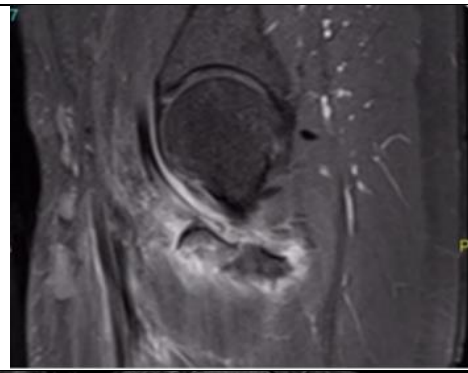


Dystrophic calcification along the chronic avulsion fracture of rectus femoris from aiis with dispropotionate osteoarthritic changes in superior aspect of the left hip joint in keeping with associated labral and joint capsule injury.

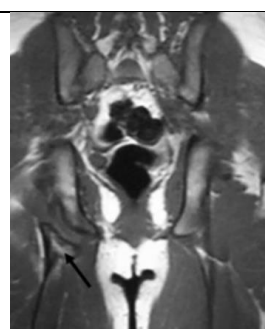


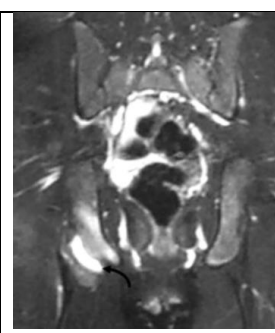
2) Lesser Trochanter Avulsion Fracture

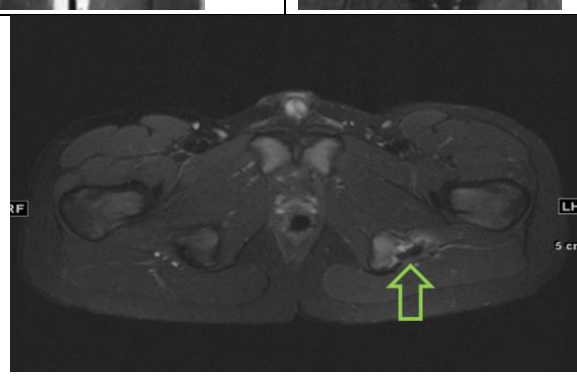




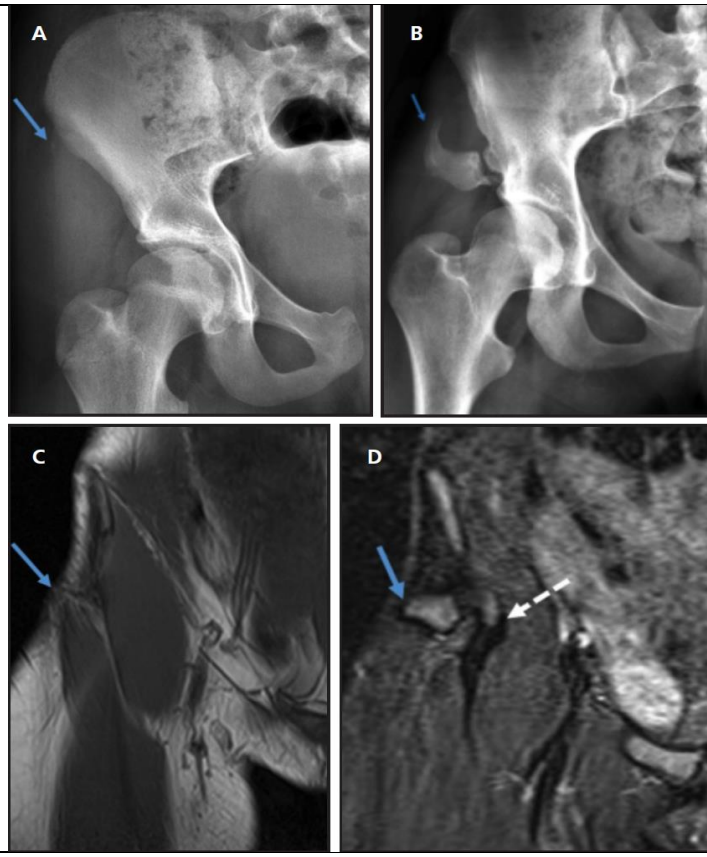
3) Ischial Tuberosity Avulsion Fracture







4) ASIS Avulsion Fracture



Hip Joint Dislocation

A) <u>Posterior Hip Dislocation (90%):</u>

- Car accident (front seat) = Dash-board Dislocation
- Femoral head lateral and superior to the acetabulum.
- Posterior rim of acetabulum is usually fractures.
- Sciatic nerve injury; 10%

B) <u>Anterior Dislocation (10%):</u>

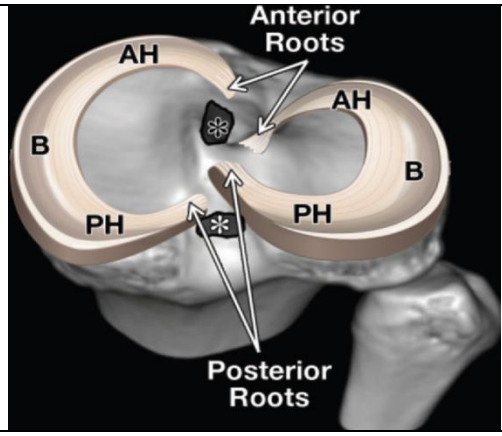
- Femoral head displaced into the obturator, pubic or iliac region.

C) <u>Interior Dislocation:</u>

- Always associated with acetabular fracture
- Femoral head protrudes into pelvic cavity.

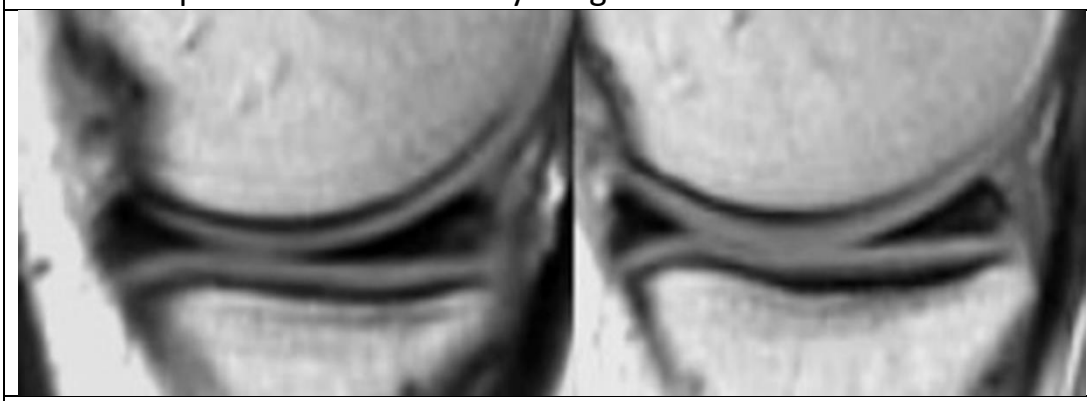
Knee Joint

Meniscus



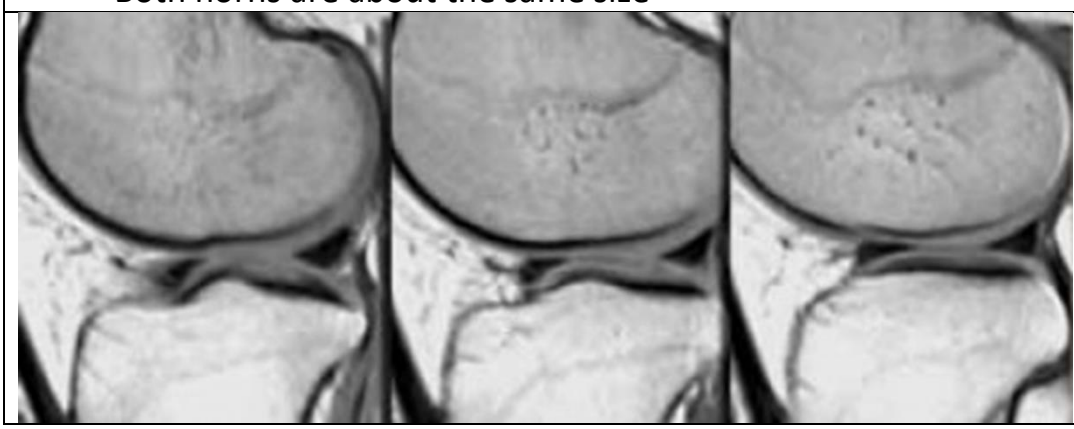
A. Medial Meniscus

- The posterior horn is always larger than the anterior horn



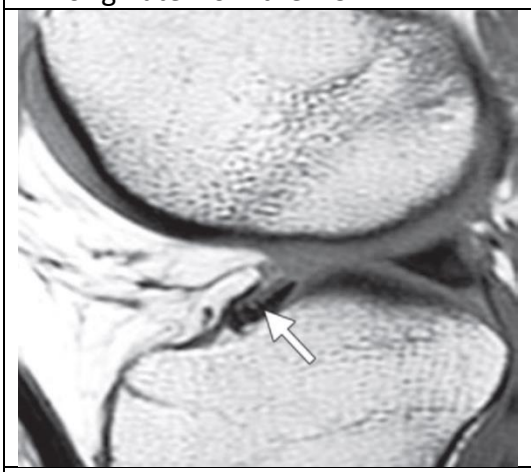
B. Lateral Meniscus

- Both horns are about the same size



Anterior horn of LM (arrow)

- ⇨ Striated appearance
- ⇨ due to contributing insertional fibers that originate from the ACL.

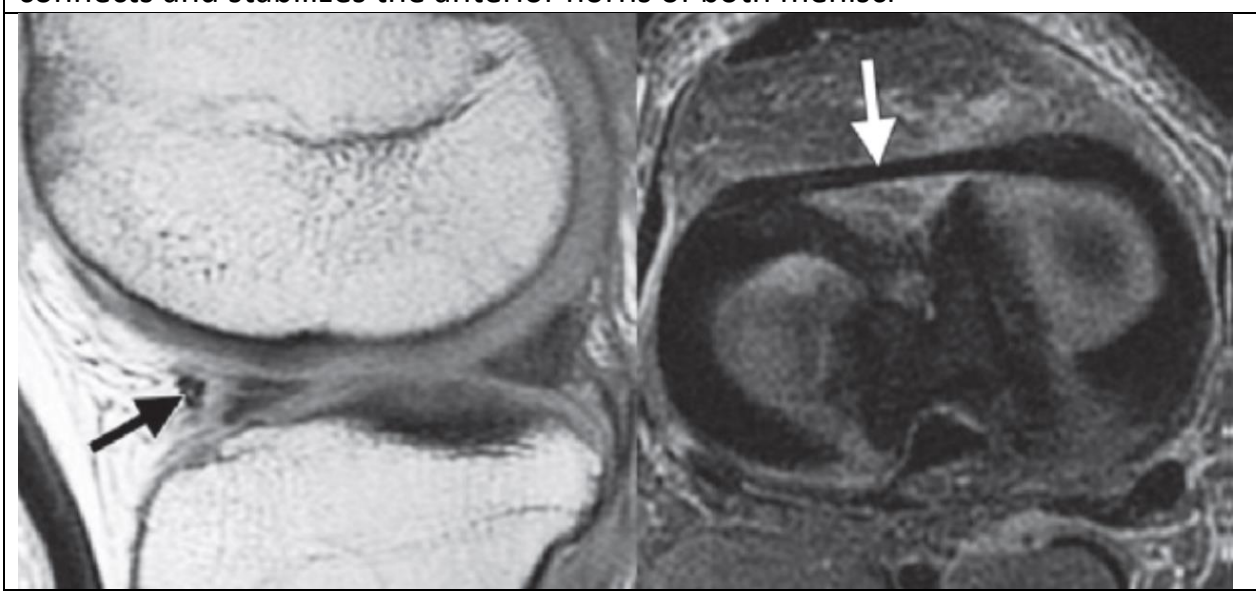


Posterior horn of LM:

Posterosuperior (arrow) and posteroinferior (arrowhead) fascicles, which form the roof and floor of the popliteal hiatus.

Transverse Meniscal Ligament:

connects and stabilizes the anterior horns of both menisci



❖Normal Variants

i. Meniscal Flounces

- MM > LM.
- Waviness or buckling of the free edge of the menisci
- Can be mistaken for tear.

ii. Discoid Meniscus

LM >>> MM

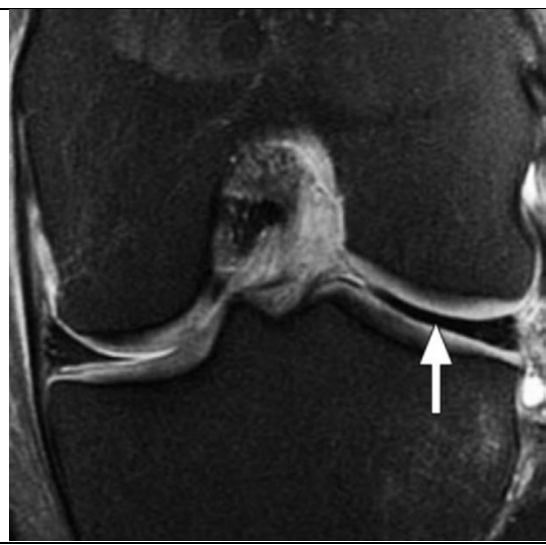
- Mid-Coronal:
  - Body of menisci measures >15 mm
- Sagittal:
  - >3 bowtie shapes on contiguous (4mm thick) images

3 variants:

(a) Complete variant has a block shaped meniscus that covers the entire tibial plateau

(b) Partial variant has a meniscus that covers 80% or less of the tibial plateau.

(c) Wrisberg variant has a thickened posterior horn, lacks the normal posterior meniscal attachments, and can cause snapping knee syndrome



iii. Meniscal Ossicle

❖Meniscal Tears

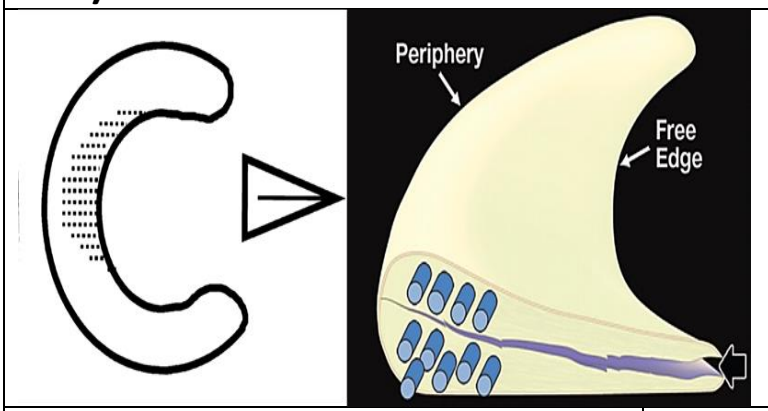
Criteria for tears

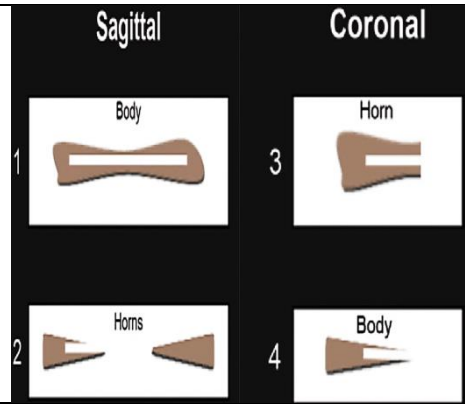
- Abnormal shape of the meniscus
- High signal intensity on PD-images.
- Two-slice-touch" rule = If these criteria are seen on > 2 images.

Basic shapes of meniscal tears:

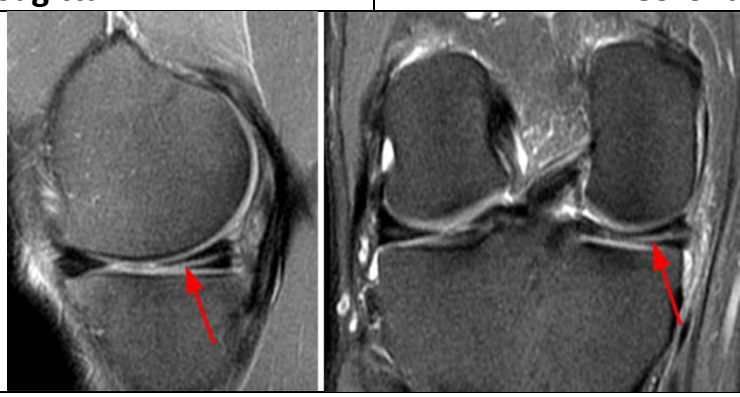
- Horizontal tear.
- Longitudinal tear.
- Radial tear.
- Root tear
- Complex tear.
- Displaced tears:
    - Bucket-handle tears.
    - Flap tears
    - Parrot tears

1) Horizontal Tear

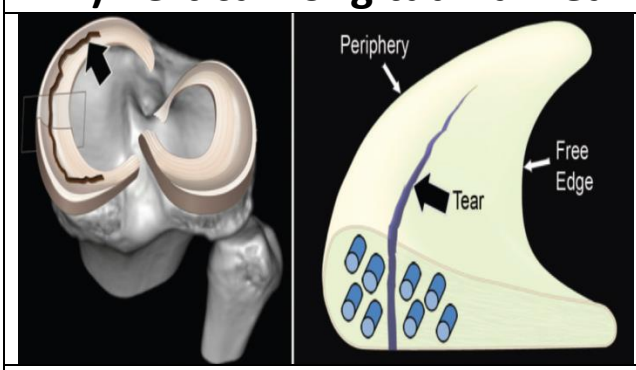


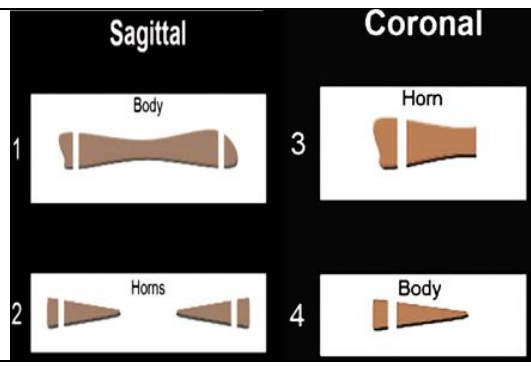


Sagittal | **Coronal**

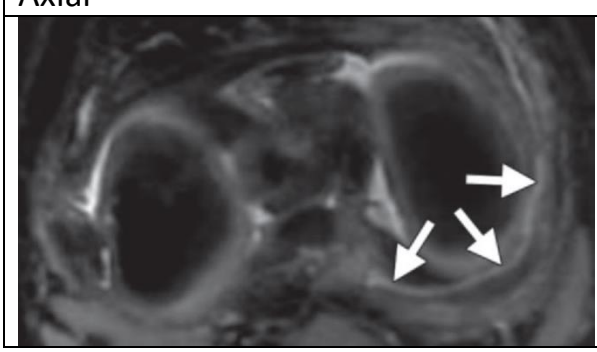


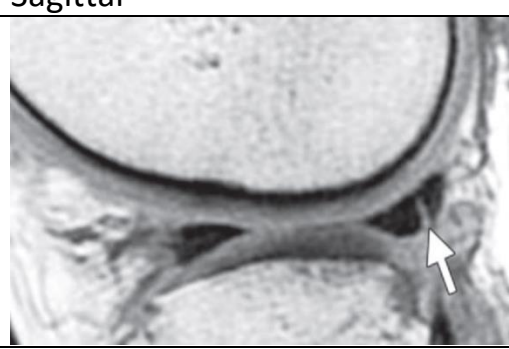
2) Vertical Longitudinal Tear



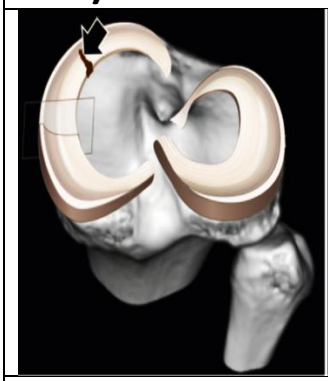


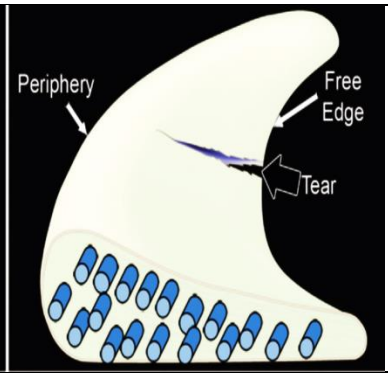
Axial | Sagittal

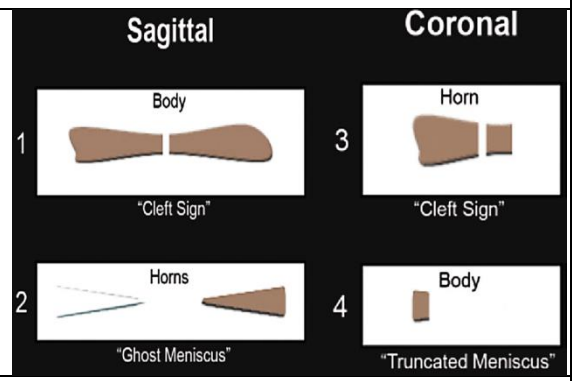




3) Vertical Radial Tear

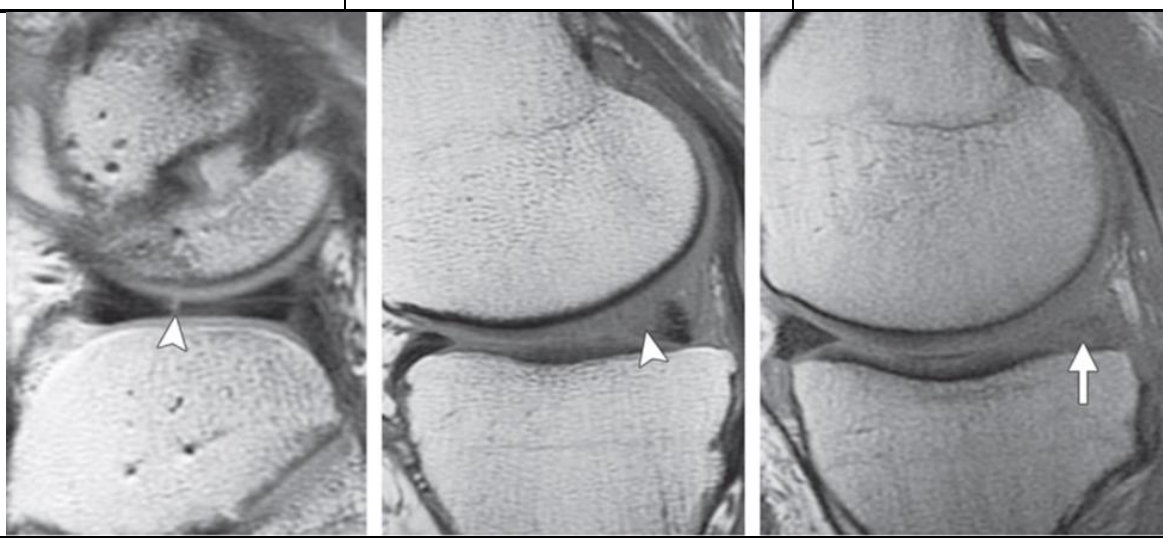






Sagittal:

Cleft sign	Truncated Triangle Sign Partial-thickness Tear	Ghost Meniscus Sign Full Thickness Tear

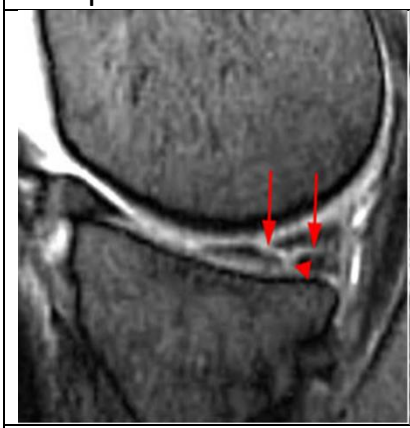


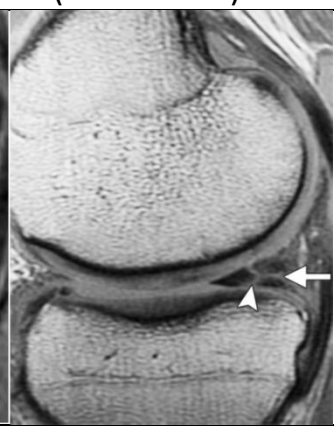
Meniscal Root Tear = Radial Tear Located At Meniscal Root

Sagittal: absent or empty meniscus-sign adjacent to PCL where meniscal root should be.

4) Complex Tear

Complex tear = Vertical tear (arrowhead) + Horizontal tear (arrow)





5) Displaced Tears

- Bucket-handle tear = displaced longitudinal tear.
- Flap tear = displaced horizontal tear.
- Parrot beak = displaced radial tear

i) Bucket Handle Tear

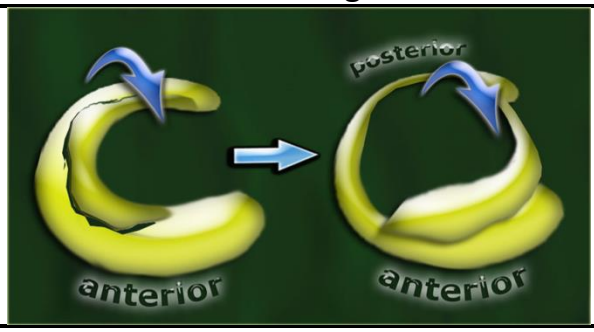
Absent bow-tie sign
Small PHMM

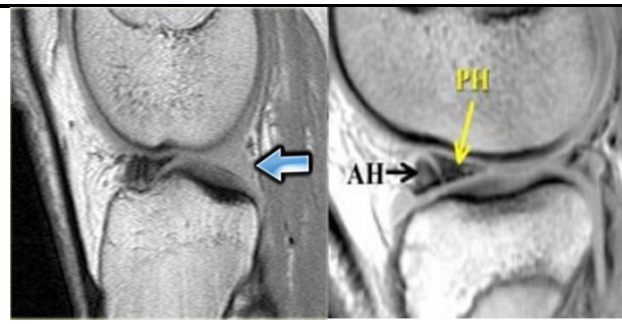
Intercondylar notch sign
Meniscal Fragement

Double PCL sign

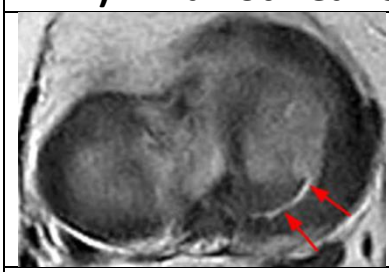
ii) Flipped Meniscus

Sagittal => Empty meniscus sign
Double anterior horn sign



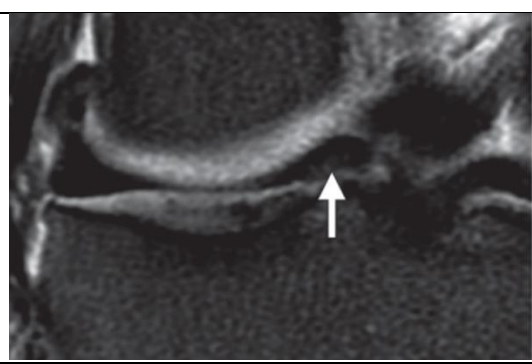


iii) Parrot Beak Shaped Oblique Tear



6) Meniscal Fraying

- Surface irregularity along meniscal free edge
- High signal intensity of the posterior root contacting the inferior articular surface (arrow
- No discrete tear



7) Meniscal Extrusion

- The peripheral margin of the meniscus extends > 3 mm beyond the edge of the tibial plateau.
- There is a close association between meniscal extrusion and root tears.

❖Post-operative Meniscus

Suture Repair:

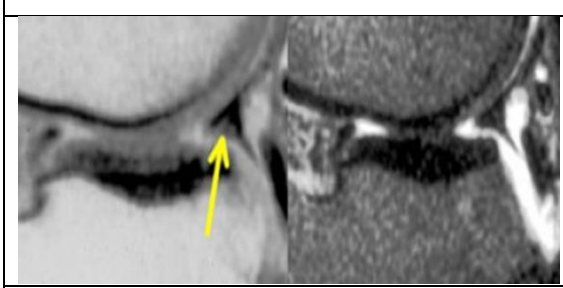
- PD is unreliable
- High signal on T2 = Tear

Partial meniscectomy:

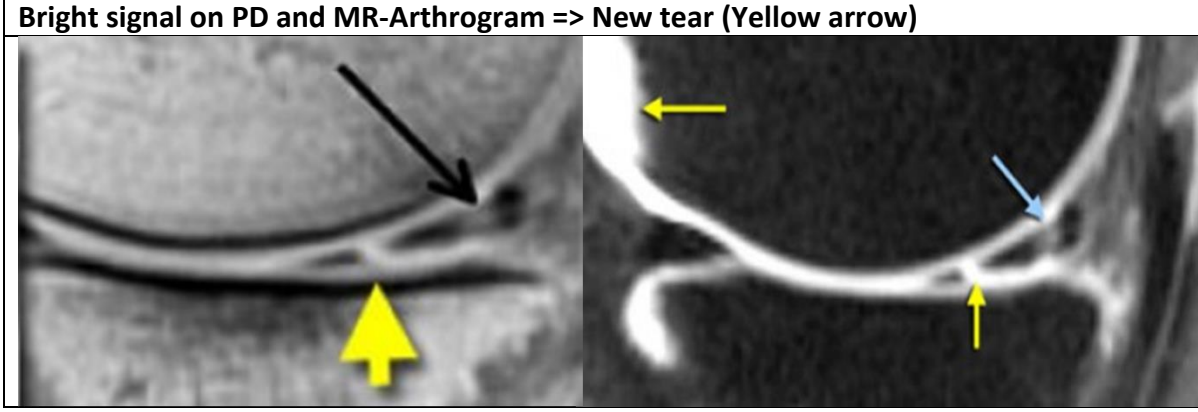
- Shape is unreliable
- Fragmentation or displaced fragment = Tear

Imaging Findings:

- Hard to evaluate because 2 important criteria (Abnormal signal + Abnormal shape) don't work.
- Sometimes differentiation between post-operative changes and re-tear is not possible on conventional MRI.
- MR Arthrogram can help in this differentiation.
- Compare with old films.

Post partial meniscectomy & Suture repair = Abnormal signal on PD + Absent on T2 FS	Post meniscal tear suture repair: Abnormal signal on PD and MR-Arthrogram => Old healed tear (Black arrow) NO Bright signal on PD and MR-Arthrogram => NO New tear (Yellow arrow)
	

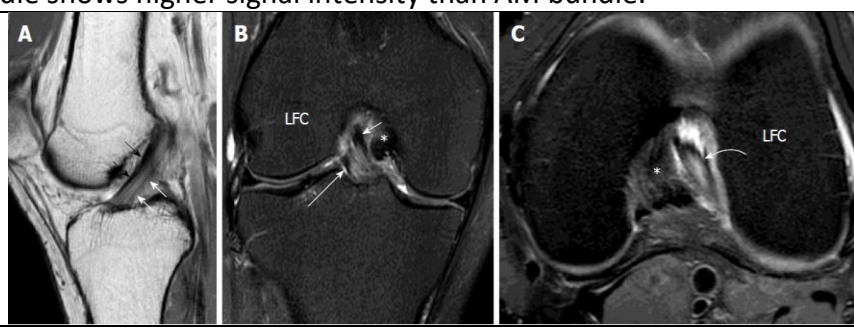
Post meniscal tear suture repair:
Abnormal signal on PD and MR-Arthrogram => Old healed tear (Black arrow)
Bright signal on PD and MR-Arthrogram => New tear (Yellow arrow)



Anterior Cruciate Ligament (ACL)

- ACL is composed of 3-5 layers of fibers. Between the fibers there can be fat or synovium or sometimes a little bit of fluid => ACL is not black on PD-images.
- Do not look at ACL on PD-images => give a false impression of pathology.
- Only look at ACL on T2W-images => ACL does not have to be entirely black.

- The anterior portion of ACL is the anteromedial (AM) bundle (black arrows)
- The posterior portion of ACL is the posterolateral (PL) bundle (white arrows).
- They cannot be well delineated from each other on this sagittal image.
- The PL bundle shows higher signal intensity than AM bundle.



Types of ACL tear:

- Complete ACL tear 80%
  - Middle one-third of the ACL (90%)
  - Close to the femoral attachments (7%)
  - Close to the tibial attachments (3%)
- Partial ACL tear (approximately 20%)

1ry signs of ACL tear

- Swollen and increased signal on T2
- Discontinuity on T2
- ACL angle that is less steep than Blumensaat's line
- Non-visualization
- Empty notch sign: fluid signal at expected ACL attachment site at the intercondylar notch (fossa) on axial and coronal images; denotes avulsion of ACL tear at its femoral attachment

ACL tear at mid-substance with fibres discontinuity	Chronic ACL tear with absence of normal ACL fibers	Acute intrasubstance ACL partial tear characterized by thickening and oedematous fibres

❖ Secondary Signs of ACL Injury

Pivot-shift injury

- Bone bruises at the middle portion of lateral femoral condyle and posterolateral tibial plateau
- Mechanism of injury is valgus stress injury to internal rotated tibia.

Lateral femoral notch sign:

- Deep depression of the middle portion of lateral femoral condyle
- Notch depth
  - 1-2 mm is suggestive of ACL tear
  - > 2 mm is diagnostic of ACL tear.

Anterior tibial translation

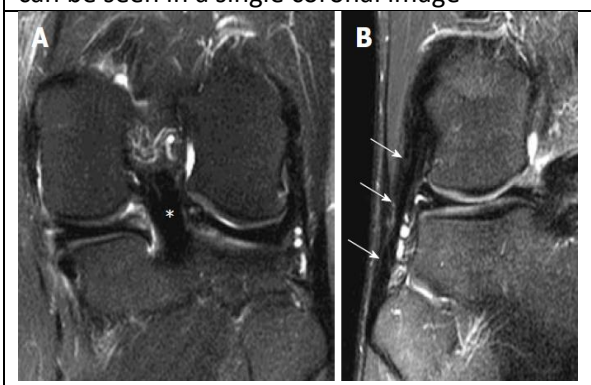
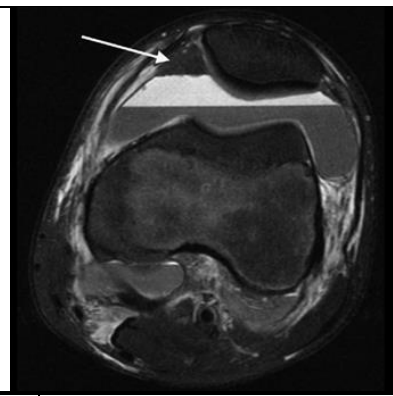
measured as the distance between two lines parallel at the mid-sagittal plane of lateral femoral condyle:

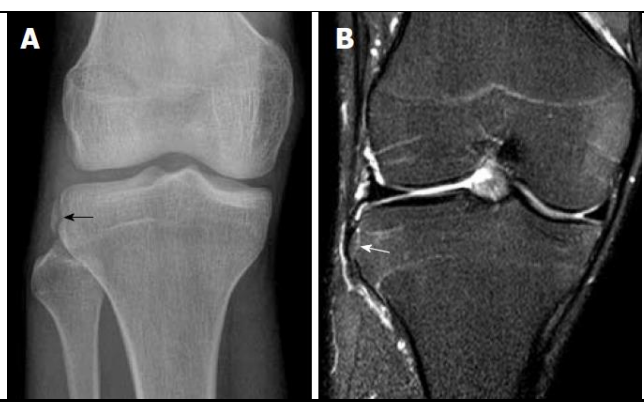
- 1st line is drawn through the most posterior corner of the lateral tibial plateau.
- 2nd line is tangent to the most posterior aspect of the lateral femoral condyle.
- Between 5 and 7 mm is suggestive of ACL tear
- > 7 mm is diagnostic of ACL tear

Uncovered posterior horn lateral meniscus

- The posterior horn of Lateral meniscus also intersects the tangent to posterior margin of tibia.

PCL buckling sign	PCL line sign	Patellar buckling sign	Shearing of fat pad
PCL posterosuperior border is concave (white arrow)	Line tangential to posterior margin of PCL is drawn (black line) and if this tangent does not intersect the posterior cortex of femur within 5cm of its distal end, PCL line is considered to be positive		Sagittal T2 FS shows fracture of Hoffa's fat pad that has isolated segment of fat (white arrows).

Coronal whole PCL and lateral collateral ligament sign	**Lipohemarthrosis**
Coronal T2-FS images: The entire PCL (*); and entire lateral collateral ligament (white arrows) can be seen in a single coronal image	fluid–fluid levels
	

Segond fracture:	**Arcuate Sign**
Avulsion fracture fragment at the lateral tibial rim	Avulsion fracture of the proximal fibula at the site of insertion of the arcuate ligament complex
	

O'Donaghue triad:

Triad of ACL, MM and MCL tear

❖ ACL Mucoid Degeneration & Ganglion Cyst

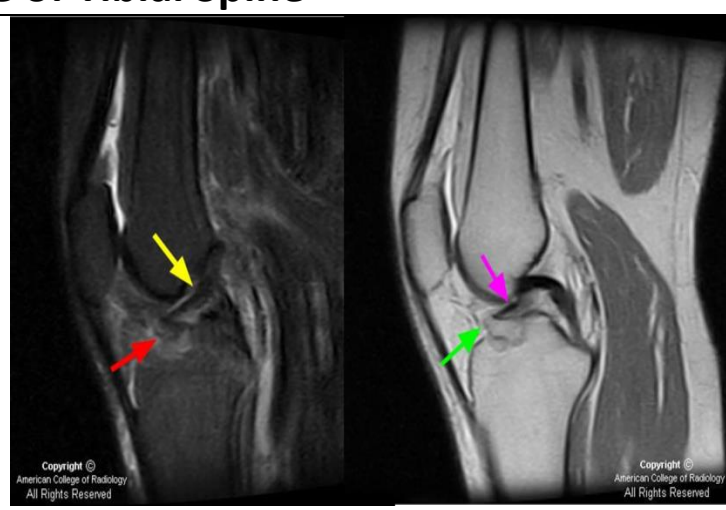
- Cystic degeneration of the ACL has been has been attributed to mucinous degeneration of connective tissue or considered as intrasubstance ACL tear

Cystic degeneration can manifest as:

- ➢ A well-defined ganglion cysts arising from the ACL
- ➢ Increased signal intensity of the whole ACL, giving rise to an appearance similar to a stalk of celery

Celery stalk sign (Mucoid degeneration)	**Ganglion cyst**

❖ ACL Avulsion Fracture of Tibial Spine



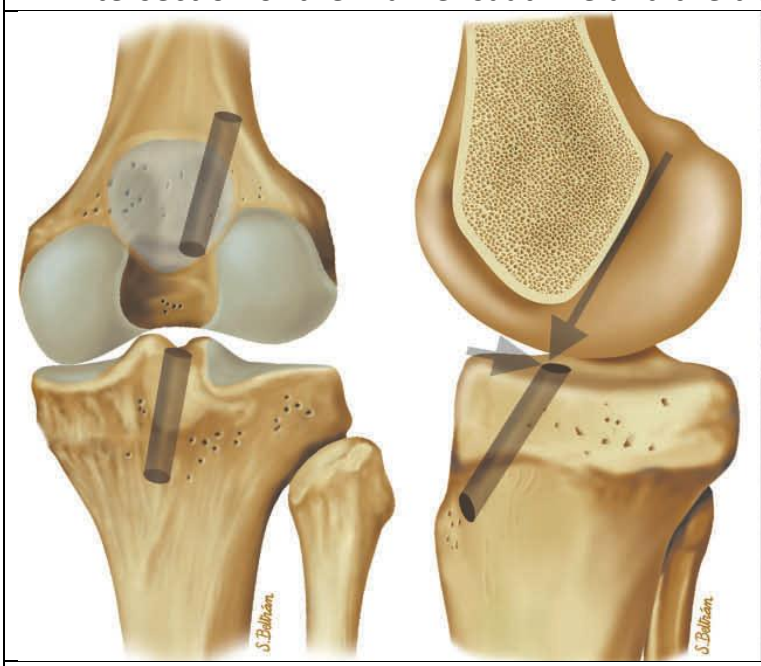
❖ ACL Graft Reconstruction

Coronal images:

- The femoral tunnel should open superiorly above lateral femoral condyle at
  - 10–11-o'clock position in the right knee
  - 1–2-o'clock position in the left knee
- The tibial tunnel should open at the intercondylar eminence

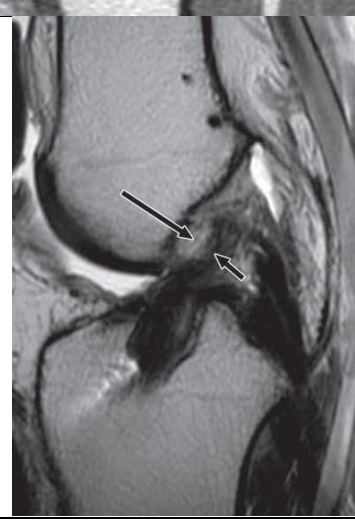
Sagittal plane:

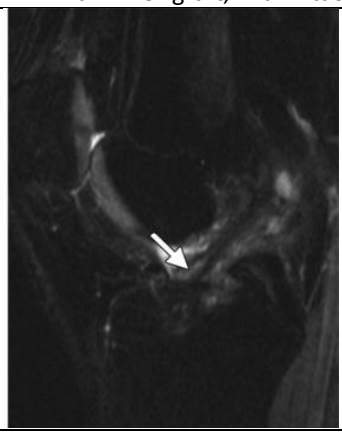
- The tibial tunnel should be oriented parallel to the projected slope of the intercondylar roof (the Blumensaat line)
- The opening of the proximal tibial tunnel should be posterior to the intersection of the Blumensaat line and the tibia



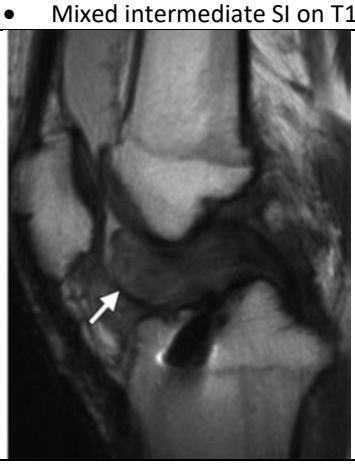
Roof Impingement:

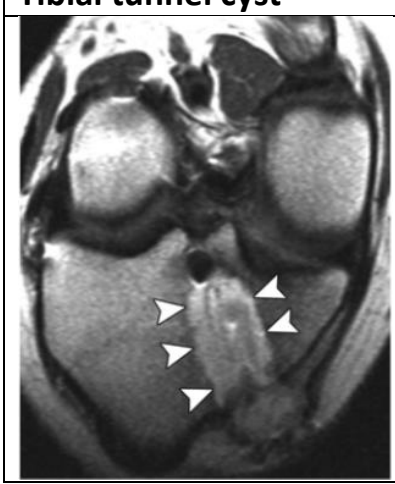
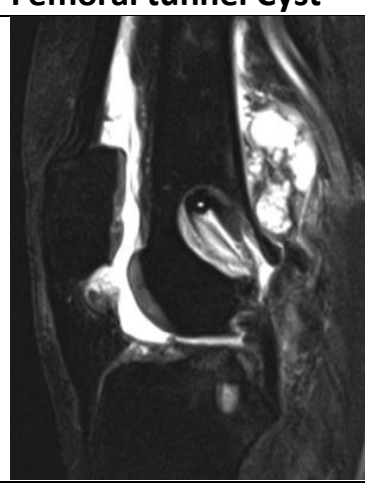
- is secondary to an abnormal position of the tibial tunnel anterior to the intersection of the Blumensaat line and the tibia when the knee is fully extended.
- The impinged graft is in contact with the anteroinferior margin of the intercondylar roof and may appear posteriorly bowed
- Signal intensity alteration selectively involves the anterior two-thirds of the graft



Partial Graft Tear:	**Complete Graft Tear**
• T2-WI: Intra-substance focal areas of high SI within ACL graft, with intact fibers	• T2 WI: absence of intact graft fibers and a fluid-filled defect
	

Arthrofibrosis

Localized = Cyclops Lesion	**Generalized Arthrofibrosis:**
• Nodular fibrous lesion that is located in the anterior intercondylar notch; sometimes it adheres to the tibial fibers of the ACL graft. • Mixed intermediate SI on T1, T2, and PD.	• is seen encasing the graft and extending into the infrapatellar fat pad and the posterior joint capsule
	

Tibial tunnel cyst	**Femoral tunnel Cyst**
	

Posterior Cruciate Ligament (PCL)

- PCL tears are less common than ACL tears.

❖ Normal PCL

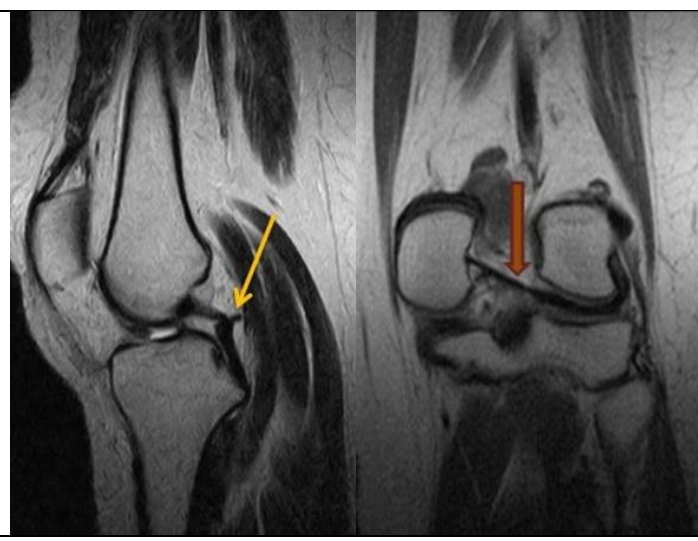
- Smooth, thin, continuous band of low signal intensity

Sagittal PD FS	Sagittal T2 FS

❖ Meniscofemoral ligament can mimic PCL tear

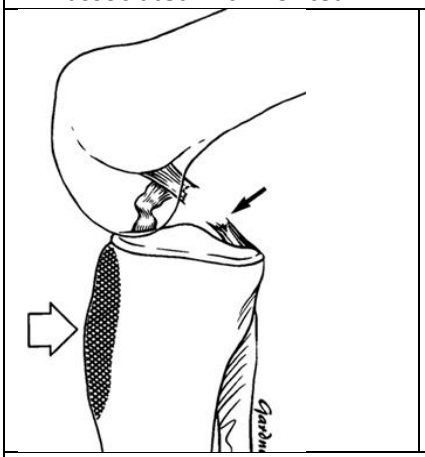
The meniscofemoral ligament (MFL) arises from the posterior horn of the lateral meniscus and passes to attach to the lateral aspect of the medial femoral condyle. It splits into two bands at PCL, which are named in relation to the PCL:

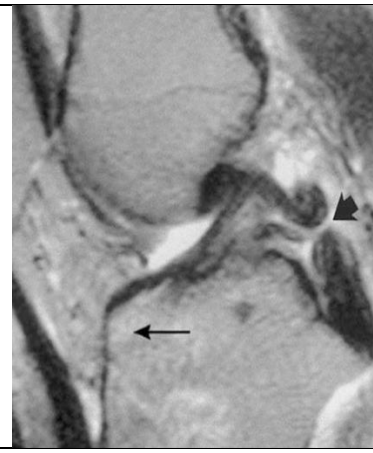
- Anterior ligament of Humphrey
- Posterior ligament of Wrisberg



❖ Dashboard Injury

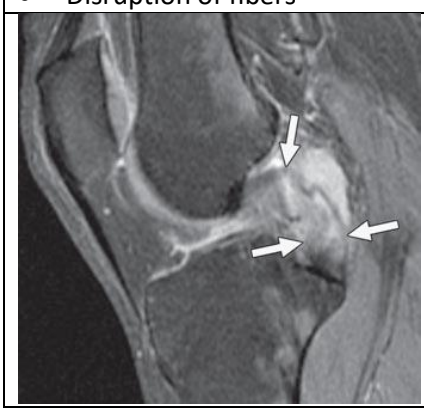
- Anterior force to tibia in a flexed knee
- (e.g. knees against dashboard in motor vehicle collision)
- Contusion pattern: anterior tibia +/- posterior patella
- associated with PCL tear



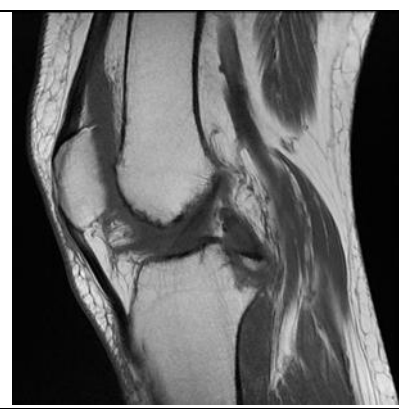


❖ PCL Tear

- Thickened PCL (>7 mm AP diameter)
- Intrasubstance increased signal intensity within ligament
- Disruption of fibers



❖ PCL Avulsion Fracture



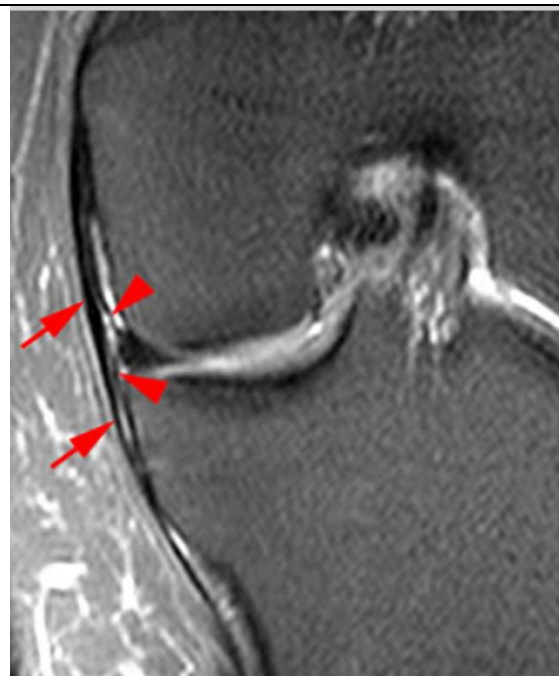
Medial Collateral Ligament Injury

2 Parts:

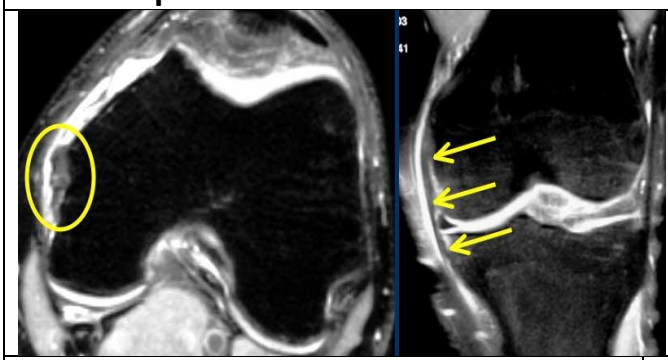
- Superficial Medial collateral ligament (Arrows)
- Meniscofemoral and meniscotibial ligaments (arrowheads).

Grading:

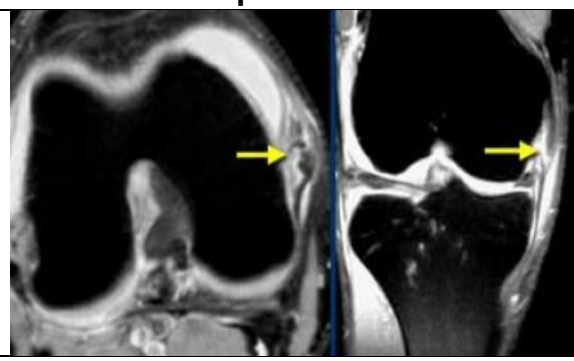
- Grade 1: (minor sprain) high signal is seen superficial to the ligament, which looks normal
- Grade 2: (severe sprain or partial tear) high signal is seen superficial to the ligament, with high signal or partial disruption of the ligament
- Grade 3: complete disruption of the ligament



Grade I sprain



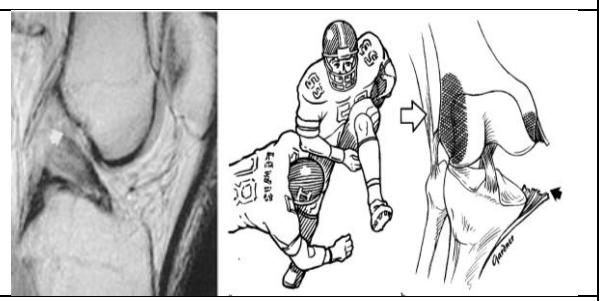
Grade II MCL Sprain



Grade III sprain

❖ Clip injury:

- Valgus stress to flexed knee
- Contusion pattern: lateral femoral condyle and lateral tibial plateau +/- medial femoral condyle from medial collateral ligament (MCL) avulsive stress
- associated with MCL injuries



❖ Stieda fracture

Bony avulsion injury of MCL at the medial femoral condyle

❖ Pellegrini-Stieda lesion

Ossified post-traumatic lesions at the medial femoral collateral ligament adjacent to the margin of the medial femoral condyle

Iliotibial Band Syndrome

- ITB syndrome is an overuse syndrome most common in long distance runners and is one of many causes of lateral knee pain.
- MRI: localized edema deep to the intact iliotibial band (yellow arrows).
- Intact lateral meniscus, lateral collateral ligament complex, bones, and the remaining soft tissues are normal.

Anterior Knee Pain

A- Patella

❖ Chondromalacia Patellae = Patellofemoral pain syndrome

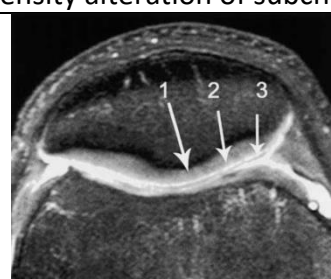
- Softening and degeneration of the articular hyaline cartilage of the patella
- is a frequent cause of anterior knee pain.
- 2 age groups:
    - Young adults => deep layer
    - Old age group => superficial layer

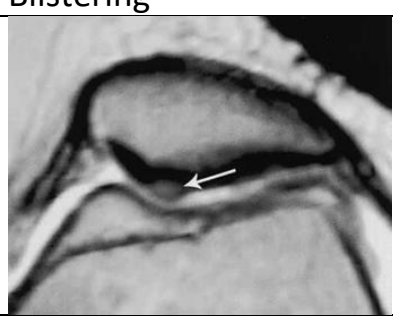
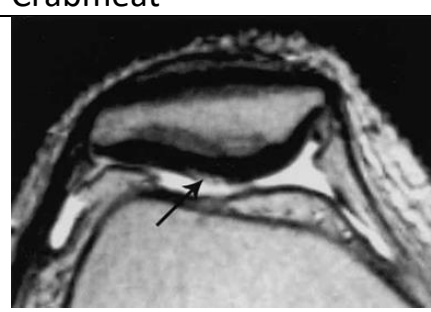
MRI Staging (Axial and Sagittal PD FS):

- Stage I: focal areas of altered signal intensity
- Stage II: mild irregularity, thinning, or swelling of the articular surface extending to the surface + Intact surface
- Stage III: deep fragmentation, "crabmeat" appearance of cartilage, or substantial thinning
- Stage IV: ulceration of cartilage + signal intensity alteration of subchondral bone

Normal:

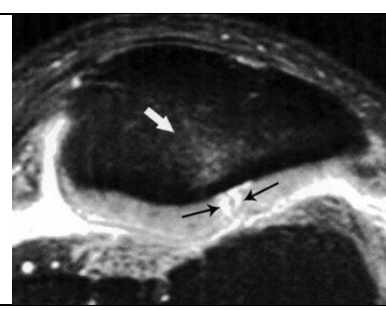
Axial PD FS of patella:
1) Deep layer exhibits intermediate signal
2) Intermediate layer has high signal
3) Superficial layer has low signal.



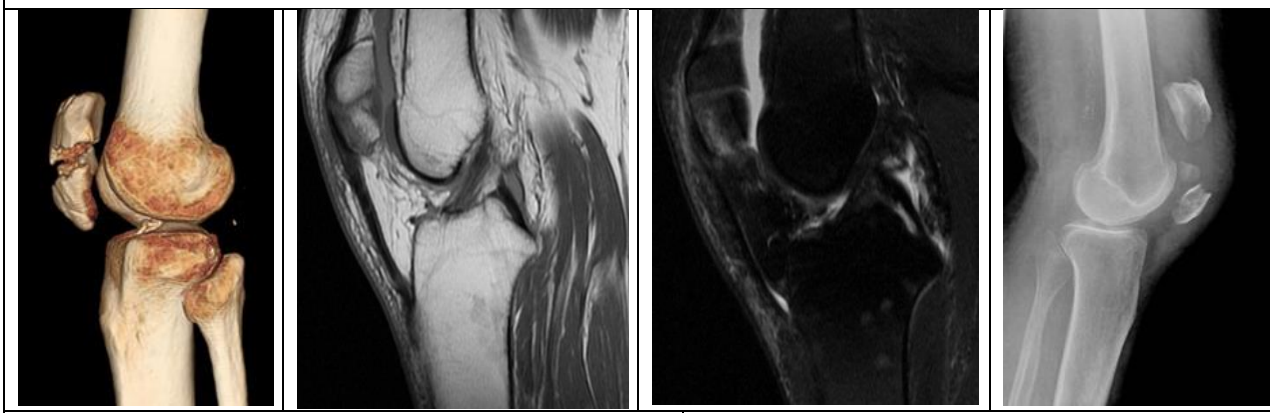
Grade 1:	Grade 2	Grade 3
Intrasubstance signal	Blistering	Crabmeat
		

Grade 4

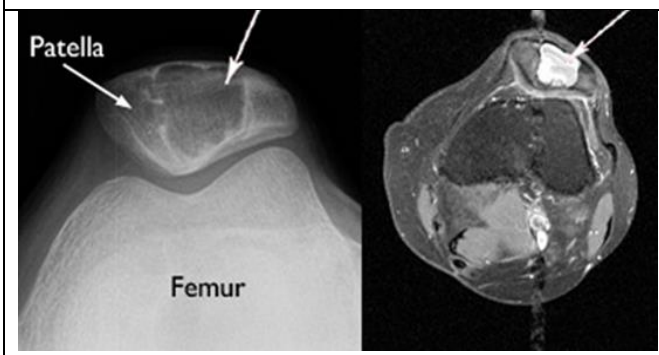
- Fissures are seen (thin arrows) extending to subchondral bone
- Patchy subchondral edema is also evident (bold white arrow).



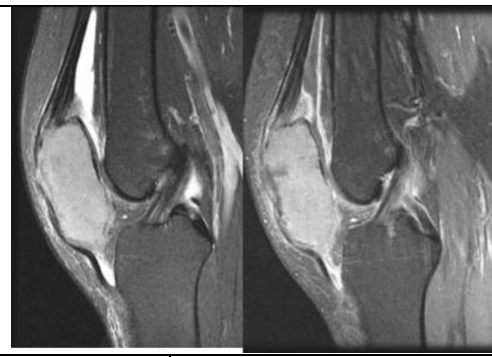
❖ Patellar Fracture



❖ Chondroblastoma Patella



❖ GCT Patella

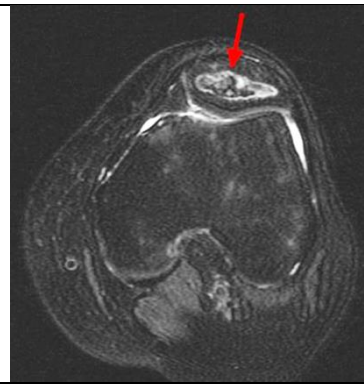


Bipartitie Patella

Tripartitie Patella

Multipartite Patella

❖ AVN Of Patella



❖ Nail-patella Syndrome

Fong Syndrome:

- Absent patella
- Iliac horns
- Nail dysplasia.

❖ Double Patella Syndrome

is considered to be diagnostic for the recessive type of multiple epiphyseal dysplasia (MED).

B- Patellar Tendon

❖ Osgood-Schlatter Syndrome

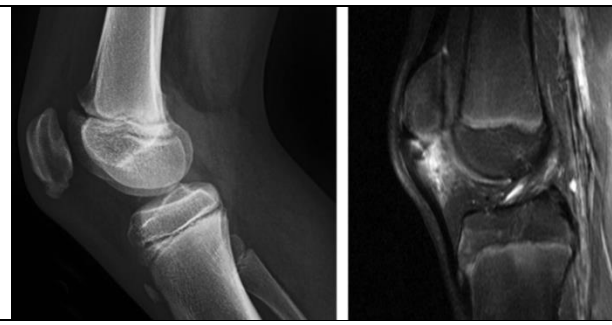
Teenage before skeletal maturity

- Bone marrow edema and fragmentation of the tibial tubercle
- Thickening and abnormal signal of the distal patellar tendon
- Edema of the Hoffa's fat pad and surrounding soft tissues

❖ Sinding-Larsen- Johansson Syndrome

Teenage before skeletal maturity

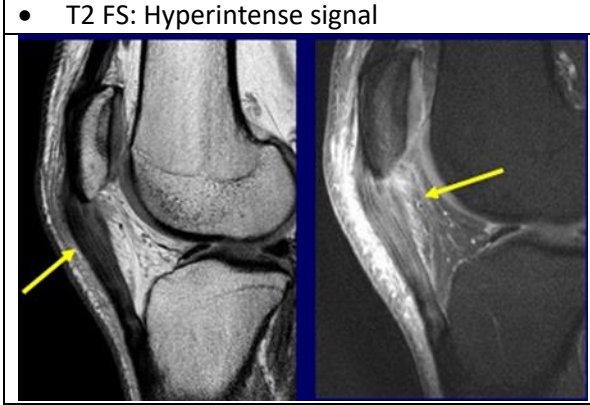
- Bone marrow edema in the inferior pole of the patella
- Thickening and abnormal signal in the proximal patellar tendon
- Edema in the Hoffa's fat pad and surrounding soft tissues



❖ Patellar Tendinosis Jumper's knee

Teenage and young adult athletes after skeletal maturity.

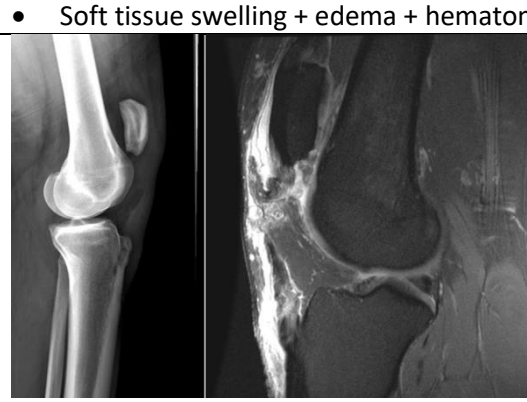
- Thickening of patellar tendon at attachment to the inferior pole of patella
- T1/PD: Intermediate signal
- T2 FS: Hyperintense signal



❖ Patellar Tendon Tear

Teenage and young adult athletes after skeletal maturity.

-
- Complete interruption of the tendon fibers
- Patella alta
- Soft tissue swelling + edema + hematoma

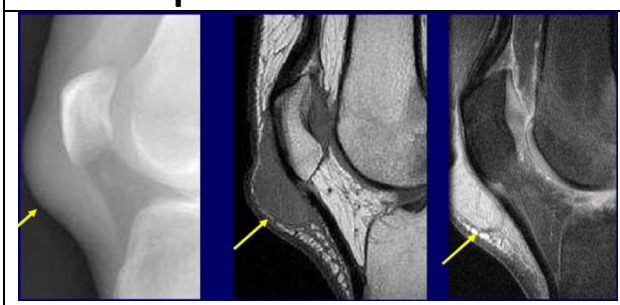


❖ Patellar Sleeve Avulsion of Inferior Pole of Patella

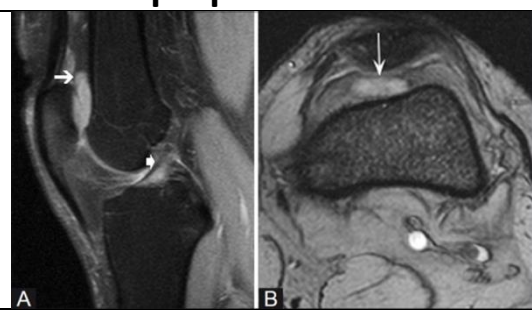
❖ Tibial Tubercle Avulsion Fractures

C- Bursa

❖ Prepatellar Bursitis



❖ Suprapatellar Bursitis



❖ Deep Infrapatellar Bursitis

❖ Superficial Infrapatellar Bursitis

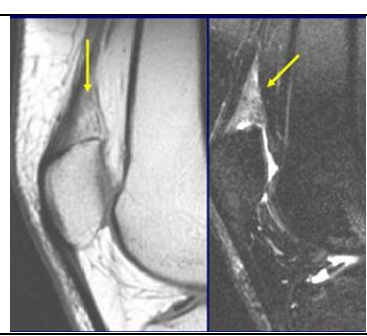
D-Fat Impingement Syndromes

3 Fat Pads

- **Anterior Suprapatellar fat pads = Quadriceps fat pad**
- **Posteriorly Suprapatellar fat pads = Prefemoral fat pad.**
- **Infrapatellar fat pad = Hoffas fat pad**

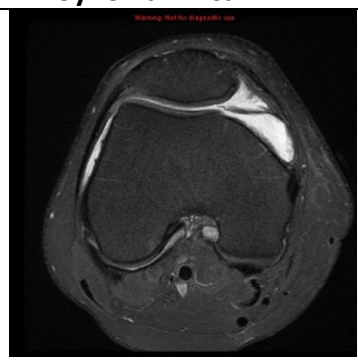
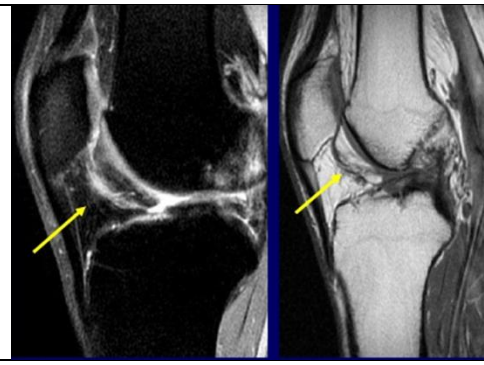
❖ Hoffa's Disease Infrapatellar Fat Pad Impingement Syndrome

❖ Quadriceps Fat Pad Impingement Syndrome

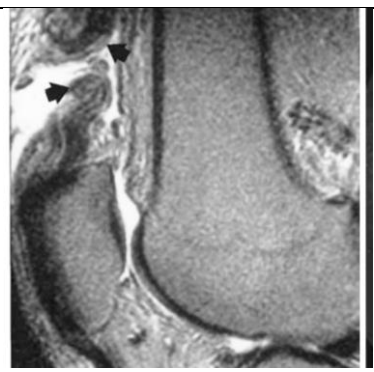


❖ Prefemoral Fat Pad Impingement Syndrome

E- Synovial Plica

❖ Supra-patellar Synovial Plica	❖ Medial-patellar Synovial Plica	❖ Infra-patellar Synovial Plica
		

F- Quadriceps Tendon

❖ Norma Trilaminar appearance	❖ Quadriceps Tendon Tear	❖ Quadriceps Myotendinous Strain
		

G-Patello-Femoral Articular Relation

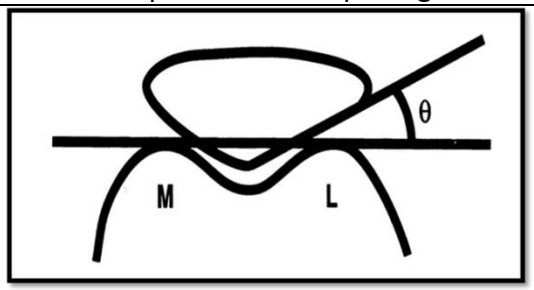
❖ **Patella Alta**

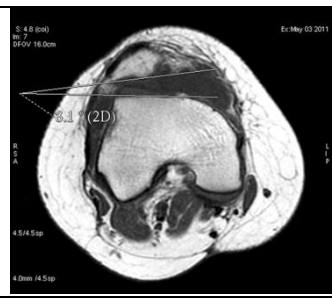
Insall–Salvati (IS) ratio
Sagittal image
Patellar tendon: Patellar length ratio
Normal value = 1± 0.13.
Patella alta > 1.3

❖ Lateral Patellar Tilt

Lateral Patellofemoral Angle:

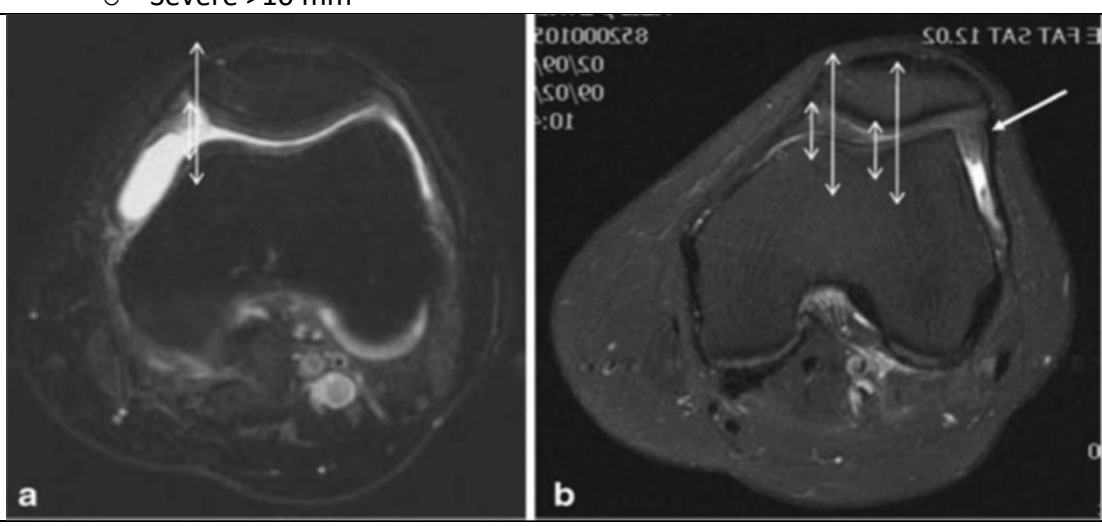
- Angle between the lines drawn along the bony lateral patellar facet and the tangent to the anterior femoral condyles.
- It is measured at the level of the patellar midpoint
- Normal opens laterally
- Lateral patellar tilt is opening medially





❖ Lateral Patellar Sublaxation

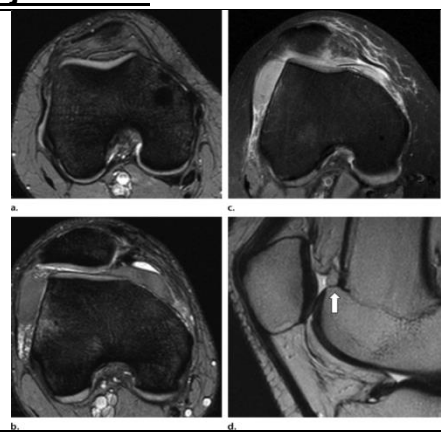
- Distance between 2 lines drawn along the medial patellar facet (short line) and medial femoral trochlea (longer line)
- Distance between 2 perpendicular lines drawn from the median ridge of the patella and the apex of the trochlear sulcus.
- Normal < 2 mm distance between 2 lines
- Lateral patellar subluxation :
    - Mild <5 mm
    - Moderate 5–10 mm
    - Severe >10 mm



❖ Trochlear Dysplasia

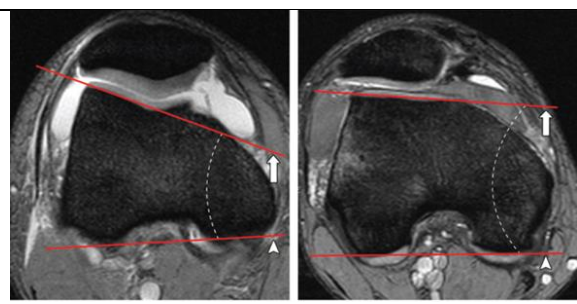
4 types according to the classification of Dejour et al

- Type A dysplasia: Trochlear morphologic structures are preserved, but the sulcus is shallow.
- Type B dysplasia: flat, horizontally oriented trochlear joint surface.
- Type C dysplasia: flat, obliquely oriented trochlear joint surface with facet asymmetry.
- Type D dysplasia: same as type C but with a prominent bone protrusion (arrow) on the parasagittal view (cliff pattern).



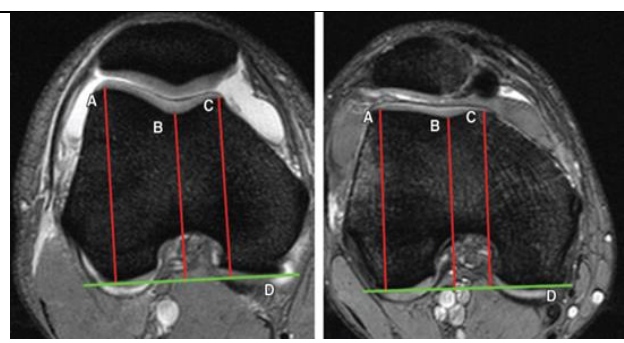
❖ Lateral Trochlear Inclination

- A line (arrow) is drawn along the lateral trochlear facet,
- A second line (arrowhead) is drawn along the posterior aspect of the femoral condyles.
- The angle between the two lines is the inclination angle (dashed line).
- Normal value = 20-25 degree
- Trochlear Dysplasia <11 degree



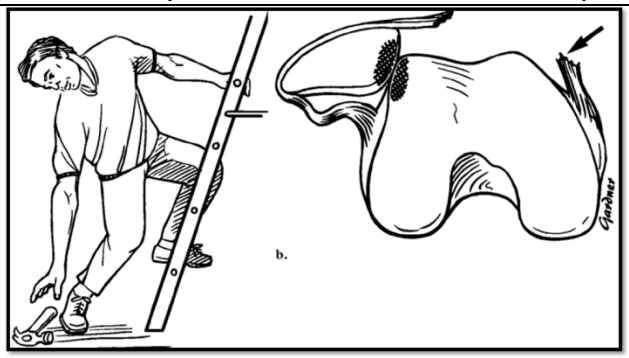
❖ Trochlear Depth

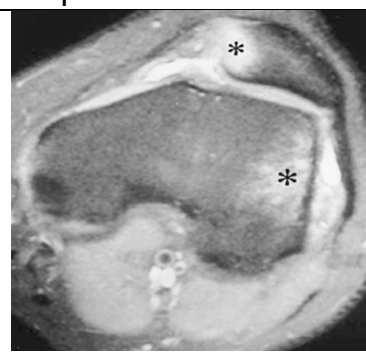
- A line drawn parallel to posterior aspect of the femoral condyles serves as a reference line (line D).
- The lines drawn perpendicular to the reference line indicate the largest AP diameters of the lateral (line A) and medial (line C) trochlear facets and the deepest point of the sulcus (line B).
- Trochlear depth = (A + C/2) − B.
- Normal depth = 12 mm.
- Trochlear dysplasia < 3 mm



❖ Lateral Patellar Dislocation

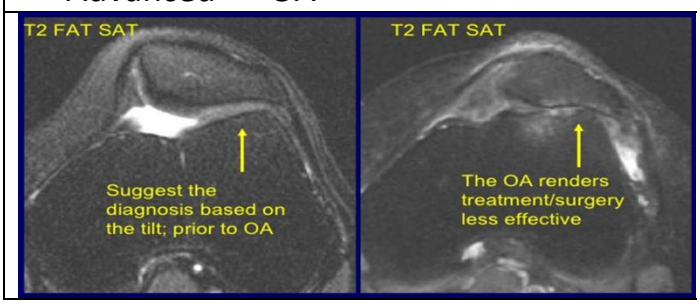
- Medial patella bone contusion.
- Lateral femoral condyle bone contusion.
- Medial patellar retinaculum is completely disrupted

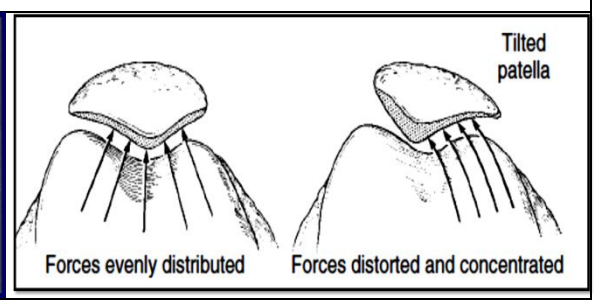




❖ Excessive Lateral Patellar Pressure Syndrome

- Young patients with anterior knee pain.
- Lateral Patellar tilt
- Narrowing of the lateral aspect of the patellofemoral joint.
- Cartilage damage (chondrosis) and Chondromalacia Patella.
- Advanced => OA





Posterolateral Corner Injury

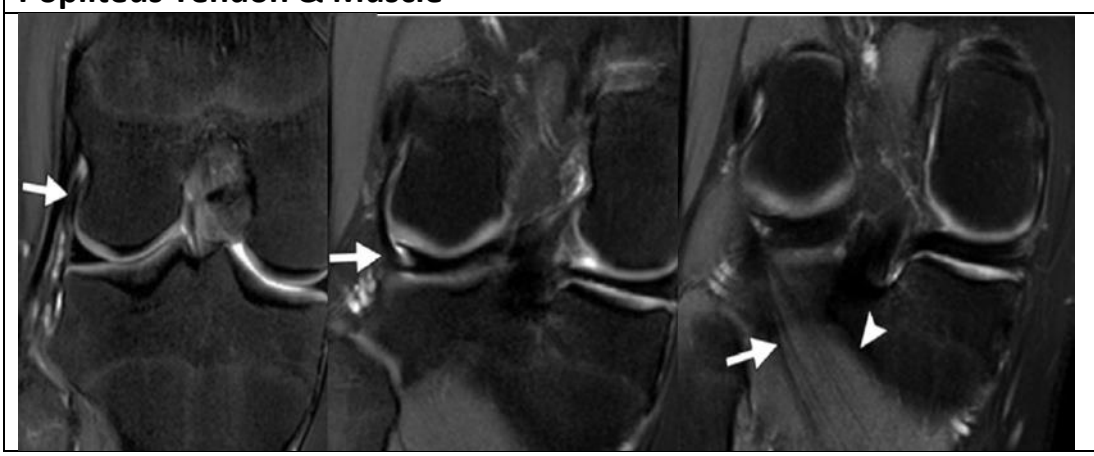
Arcuate Complex Injury

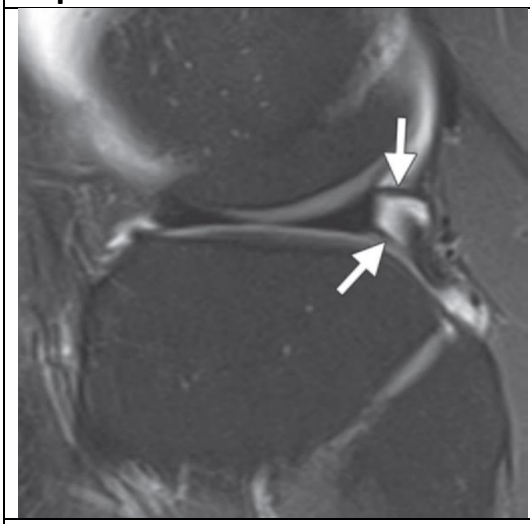
<u>Posterolateral Corner COMPLEX</u>

- Popliteus tendon and muscle.
- Popliteal fibular ligament
- Popliteal meniscal ligament
- Lateral (fibular) collateral ligament
- Arcuate ligament
- Posterior third of the lateral capsule
- Fabello-fibular ligament
- Biceps femoris tendon
- Lateral gastrocnemius muscle

Lateral collateral ligament

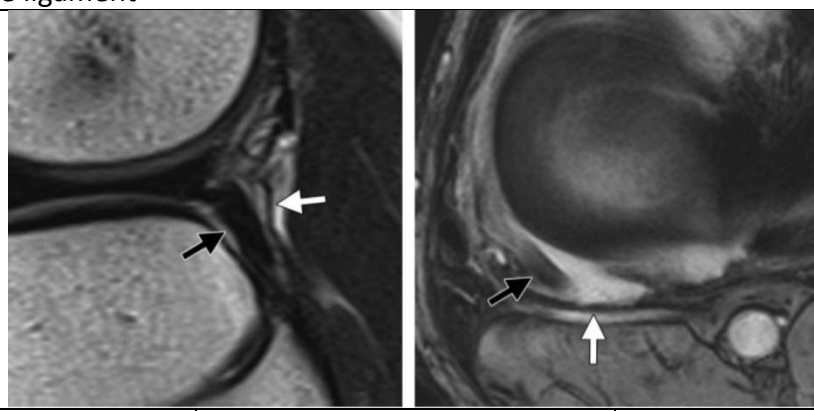
Popliteus Tendon & Muscle



Popliteo-meniscal Ligament Superior & Inferior Fascicles	Popliteo-Fibular Ligament
	

Arcuate Ligament

- Arcuate ligament (white arrow) posterior to the popliteus tendon (black arrow).
- An intact posterior capsule at the lateral joint line (white arrow). This is a reliable sign of an intact arcuate ligament



Biceps Femoris Tendon	Popliteofibular Ligament	Fabellofibular Ligament

A- BONE INJURIES

❖ Pivot-shift injury

- Kissing contusions of lateral femoral condyle and posterolateral tibial plateau.
- ACL complete tear.
- Vertical tear of PHMM
- MCL sprain

❖ Hyperextension varus injury

- Kissing contusions of antero-medial femoral condyle and medial tibial plateau.
- Associated ACL, PCL and meniscal injury

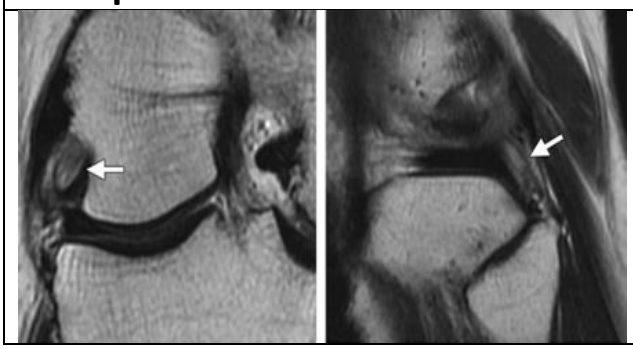
❖ Segond Fracture

❖ Arcuate Avulsion Fracture

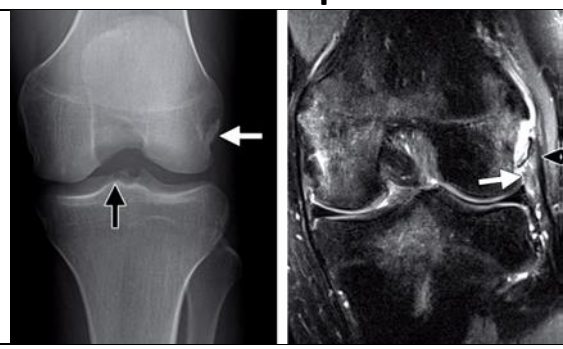
❖ Lateral Femoral Condyle Notch Sign

B- Popliteus Tendon

❖ **Popliteus Tendinosis**

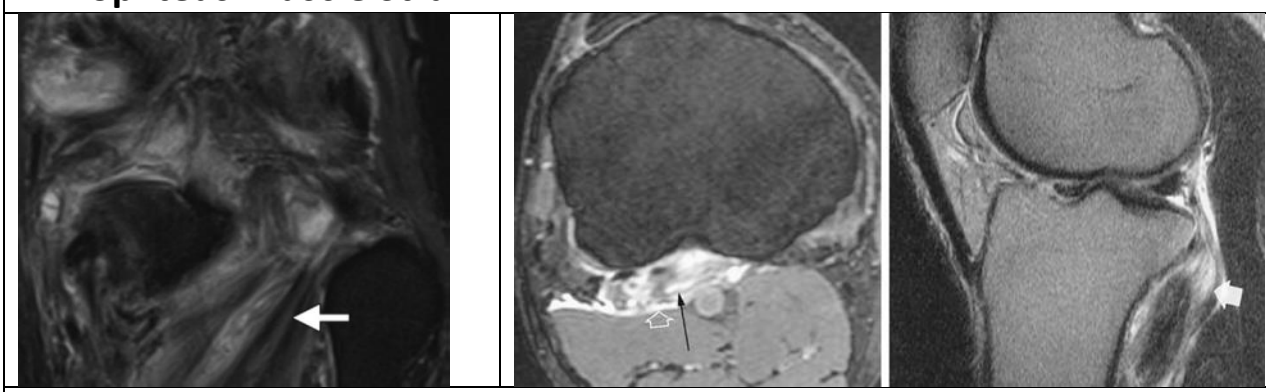


❖ **Avulsion Of Popliteal Notch**

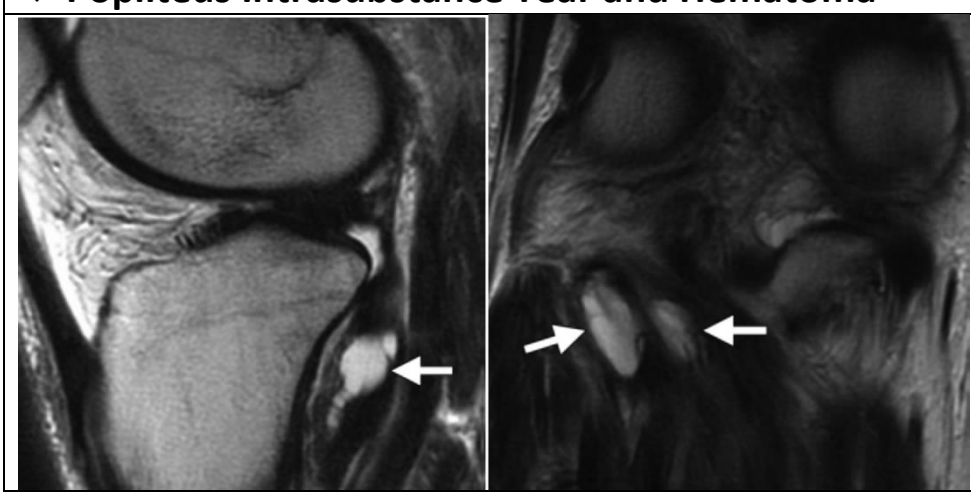


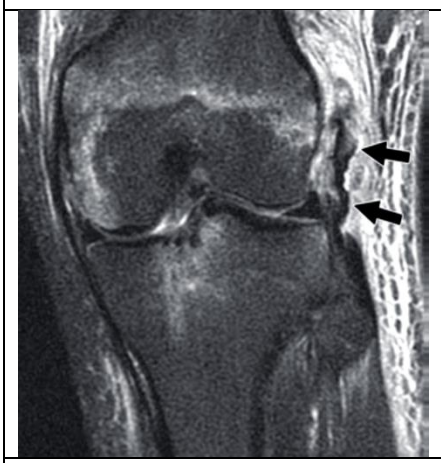
C- Popliteus Muscle

❖ **Popliteus Muscle Strain**

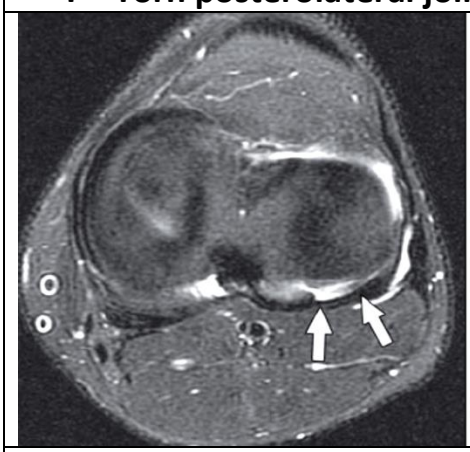
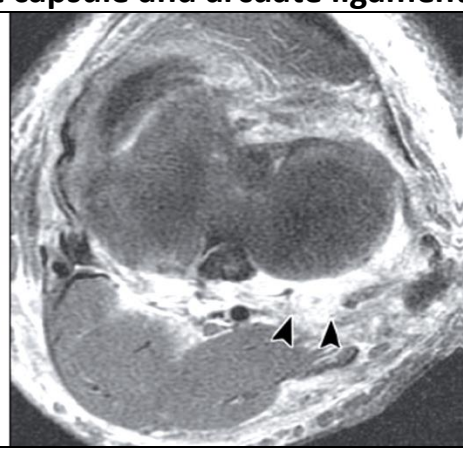


❖ **Popliteus Intrasubstance Tear and Hematoma**

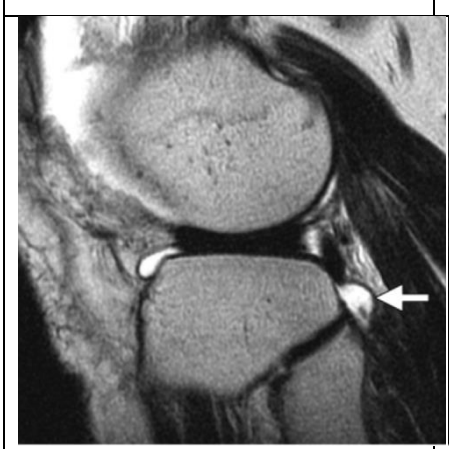
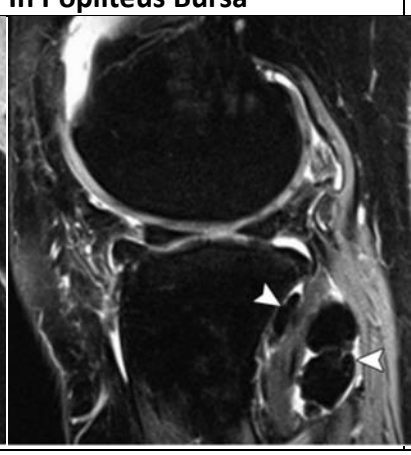
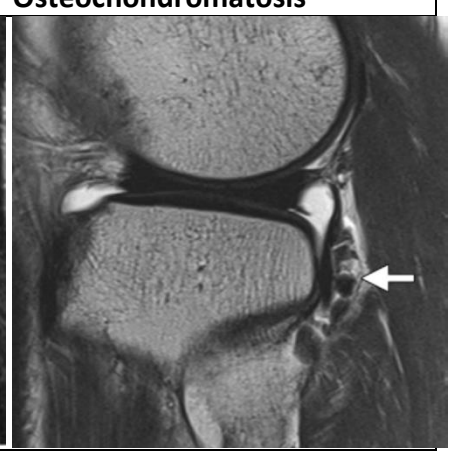


D- Torn Fibular Collateral Ligament	E- Torn Biceps Femoris Tendon
	

F- Torn posterolateral joint capsule and arcuate ligament

G- Popliteal Bursa

Popliteus Bursa	Osteoarthritis Loose Bodies In Popliteus Bursa	Synovial Osteochondromatosis
		

❖ **Type and timing of treatment of posterolateral corner injury depend on:**
- ➢ **Concomitant injuries: ACL, PCL and meniscal injuries**
- ➢ **Grade of injury and individual level of physical activity.**

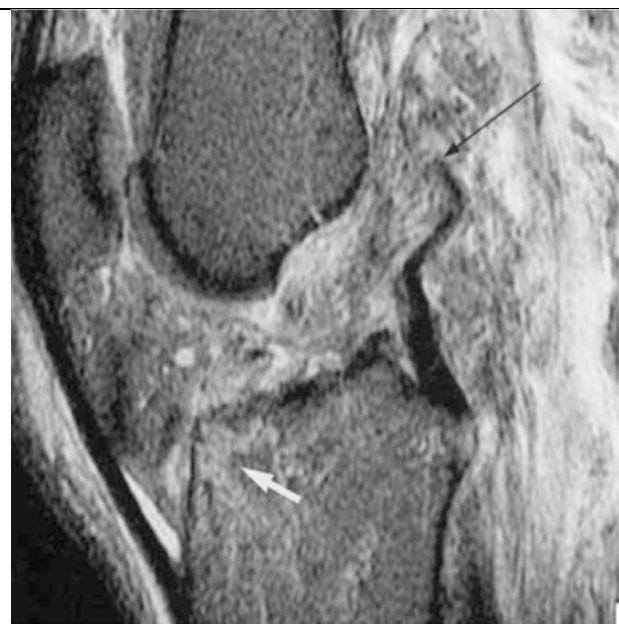
❖ **Associations of Posterolateral Corner Injury of the Knee:**

➢ **Torn Fibular collateral ligament +**
➢ **Edematous changes at posterolateral aspect of the knee**

➢ **Torn ACL**

➢ **Intact ilio-tibial band**

➢ **Torn PCL**



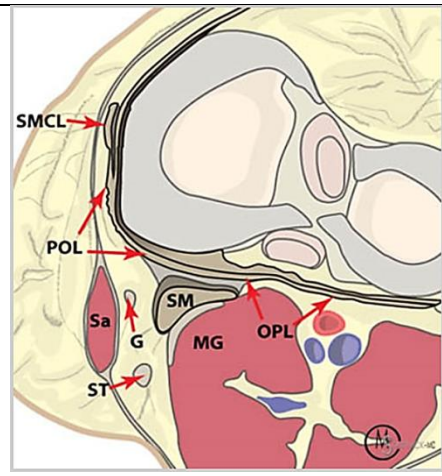
Posteromedial Corner Injury of KNEE

Posterolateral Corner COMPLEX

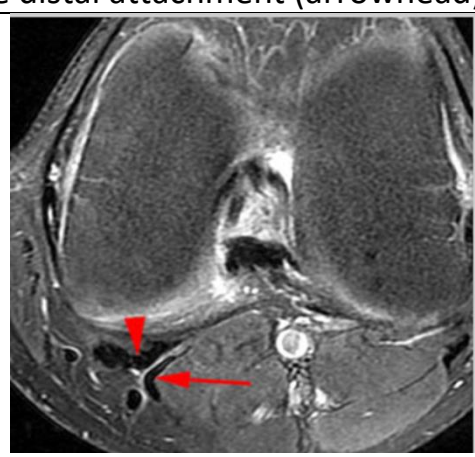
- Posterior Oblique Ligament (POL)
- Oblique Popliteal Ligament (OPL)
- Posterior Horn Of The Medial Meniscus (PHMM)

- Medial Head Of The Gastrocnemius (MG)
- Semimembranosus Tendon (SM)

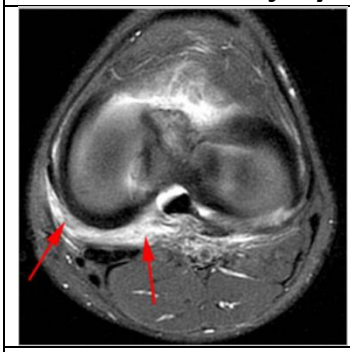
- Sartorius (Sa)
- Gracilis tendon (G)
- Semitendinosis (ST)



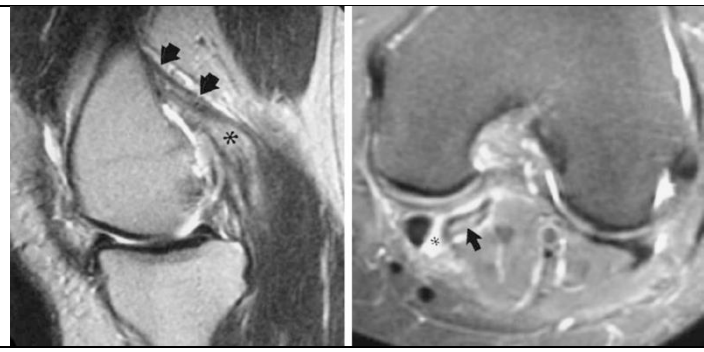
- Origin of medial head of the gastrocnemius along the posteromedial aspect of the medial femoral condyle (arrow).
- The semimembranosus tendon fan like distal attachment (arrowhead).



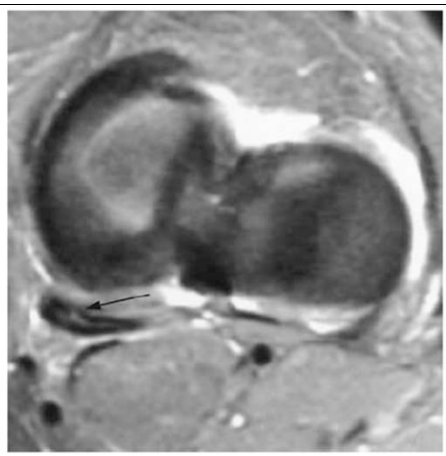
❖ **Posterior Joint Capsule + OPL & POL Injury**



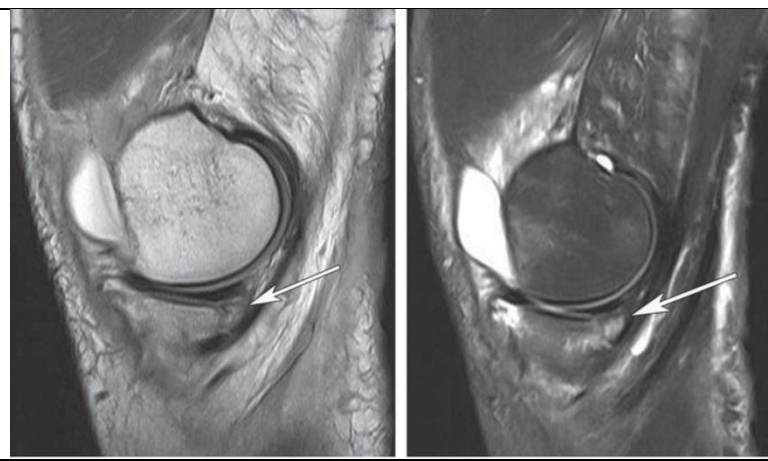
❖ **Medial head of Gastrocnemius Partial Tear**



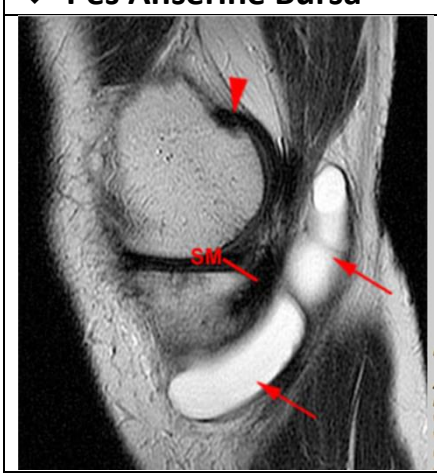
❖ **Semimembranosus Tendon Partial Tear**

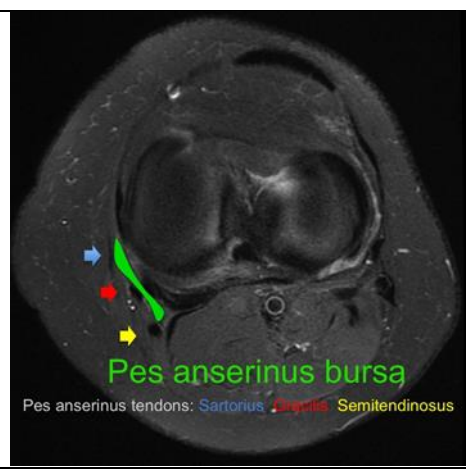


❖ **Semimembranosus Tendon Avulsion Fracture**



❖ **Pes Anserine Bursa**





Posterior Knee Pain

- PCL injury
- Popliteal cyst (Baker's cyst)
- Planter's tendon rupture
- Hamstring Muscle injury
- DVT

A- Baker cyst (Popliteal Cyst)

- Fluid-filled distended synovial-lined lesions arising in the popliteal fossa between the medial head of the gastrocnemius and the semimembranosus tendons via a communication with the knee joint.

Radiology:

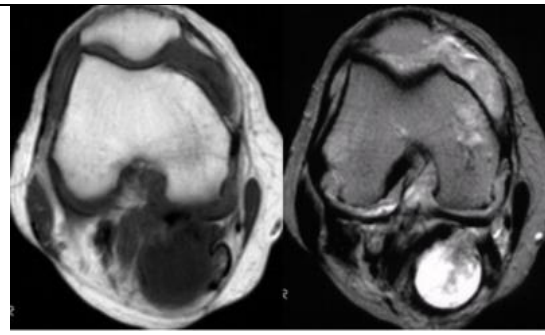
- A well-defined cyst with a 'neck' at its deepest extent, extending into joint space between semimembranosus tendon and medial head of gastrocnemius

Complications

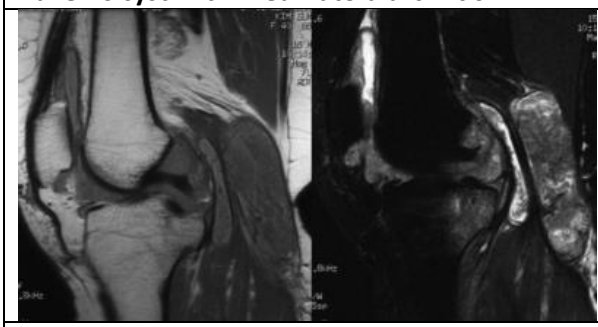
i) **Dissection:** the cyst usually dissects inferomedially but can dissect proximally, anteriorly, inter-muscularly or intra-muscularly
ii) **Rupture:** leaking of cyst fluid into the popliteal fossa, between fascial planes and surrounding the hamstrings and medial gastrocnemius muscles + edema of the soft tissue and irregularity of the cyst wall
iii) **Compression:** of the popliteal vessels and tibial nerve
iv) **Compartment syndrome**

Baker's cyst association with osteoarthritis

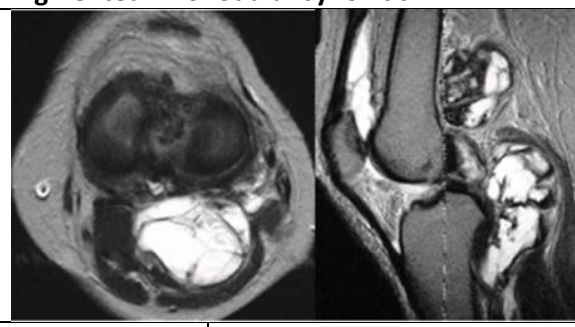
Baker's cyst with infectious arthritis and internal debris



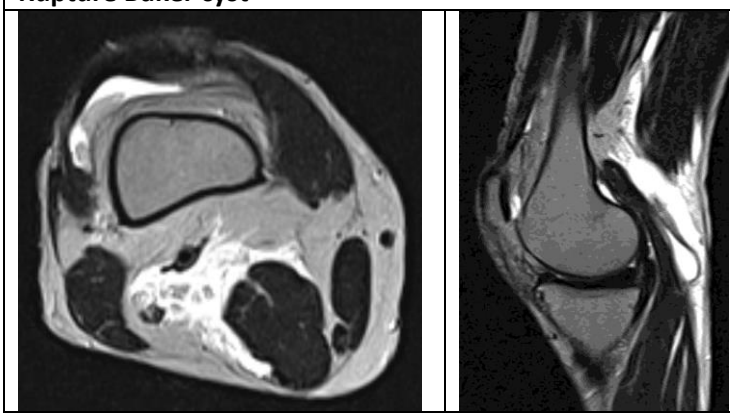
Baker 's cyst with rheumatoid arthritis



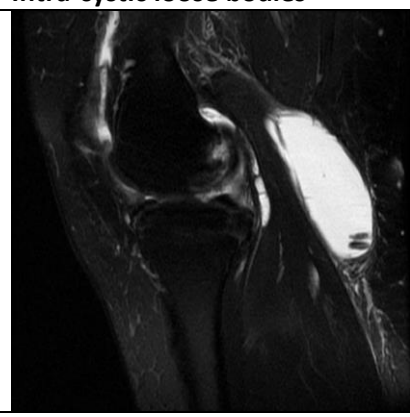
Pigmented villonodular synovitis



Rupture Baker cyst



Intra-cystic loose bodies



B- Tennis Leg

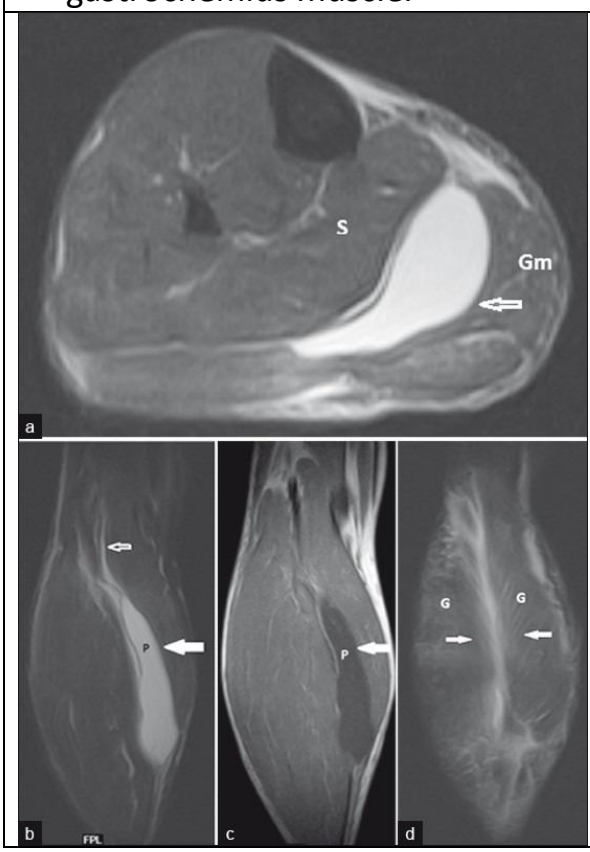
- Middle-aged patients
- Mechanism of injury: forced dorsiflexion of ankle with knee in extension.
- The injury may be accompanied by an audible “pop” in the calf, with subsequent pain and swelling

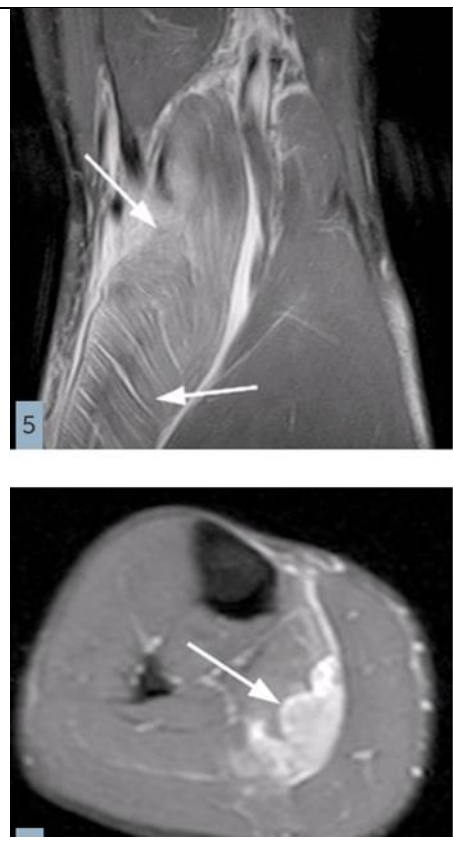
2 identified mechanisms

- Tear of myotendinous junction of the medial head of the gastrocnemius
- Rupture of plantaris tendon (now thought to be an uncommon cause)
- Both findings have been found in isolation or together.

Radiology:

- A high T2 signal fluid between the soleus muscle and medial head of gastrocnemius muscle.
- Edema or tear of medial head of the gastrocnemius or soleus muscles.



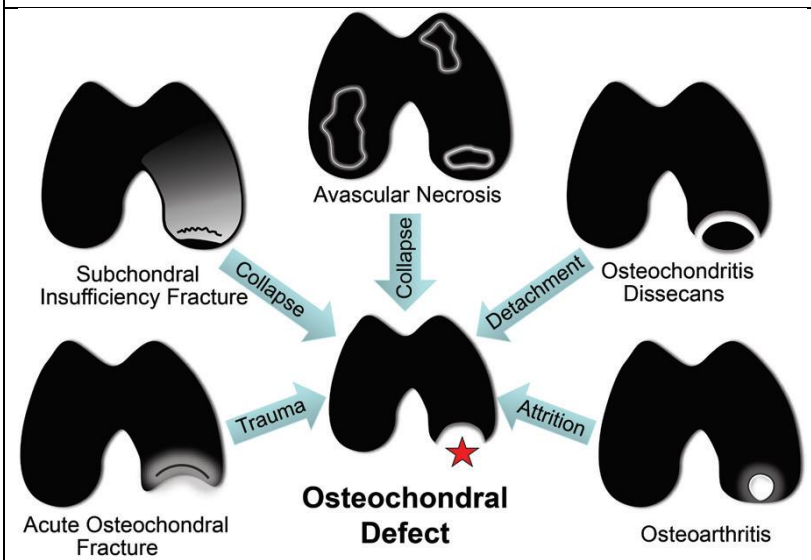


Osteochondral Lesions

- **Degenerative Osteoarthritis.**
- **Osteochondral Fracture.**
- **Osteochondritis Dissecans (OCD)**
- **Spontaneous Osteonecrosis (SONK)**
- **Primary Osteonecrosis (AVN)**

Osteochondral Defect:

- An osteochondral defect of the femoral condyle (*) may be the result of several acute and chronic conditions that produce a surface deformity with a localized defect of the articular cartilage and subchondral bone.



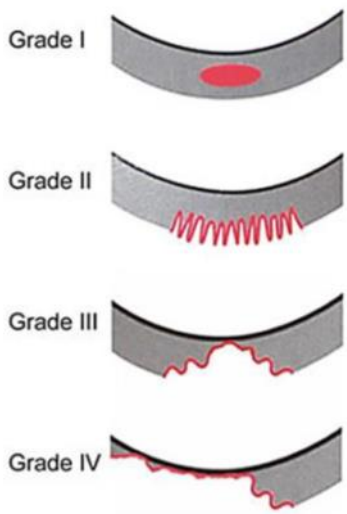
A- Degenerative Osteoarthritis

- Osteoarthritis of the knee joint is extremely common.
- Degeneration of articular cartilage is the pathologic hallmark of osteoarthritis osteoarthritis; however, articular cartilage has no pain fibers and thus cannot be the source of pain in patients with degenerative joint disease.
- Subchondral bone marrow is richly innervated with nociceptive pain fibers and may be a source of pain in patients with symptomatic degenerative joint disease

❖ Outerbridge Classification of Cartilage injury

Grade	MRI features	Arthroscopy
I	FS PD focal areas of hyperintensity within normal contour	Softening by arthroscopy
II	FS PD fissure or blister-like swelling of articular cartilage extending to surface	Fissuring and fibrillation within soft areas of articular cartilage (1-2 mm deep)
III	FS PD focal ulcerations and "crab meat" lesions	Partial thickness cartilage loss >2 mm deep
IV	FS PD full-thickness cartilage loss with underlying bone reactive changes	Ulceration with exposed subchondral bone

FS PD: Fat saturated Proton density



Bone marrow edema-like lesions:

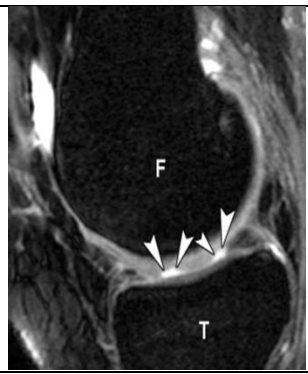
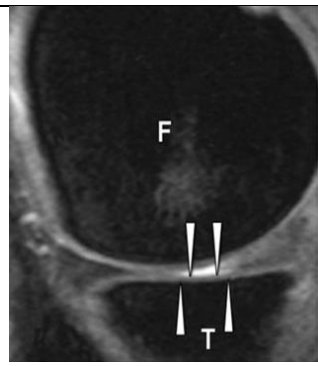
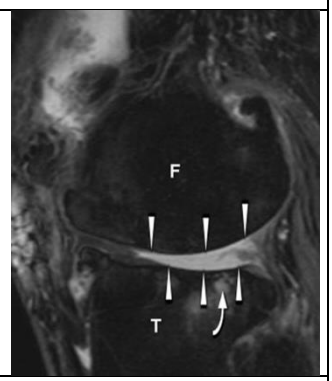
- ill-defined subchondral area
  - STIR: hyperintensity
  - T1: hypointensity.
- The most common histologic findings in bone marrow edema-like lesions include bone necrosis, fibrosis, hemorrhage, and trabecular abnormalities.

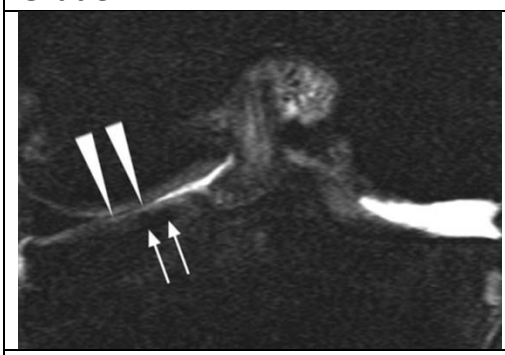
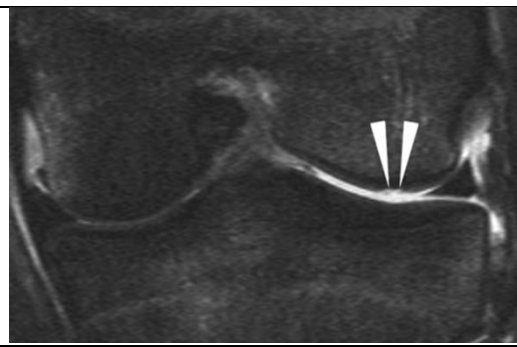
Subchondral cyst-like lesions:

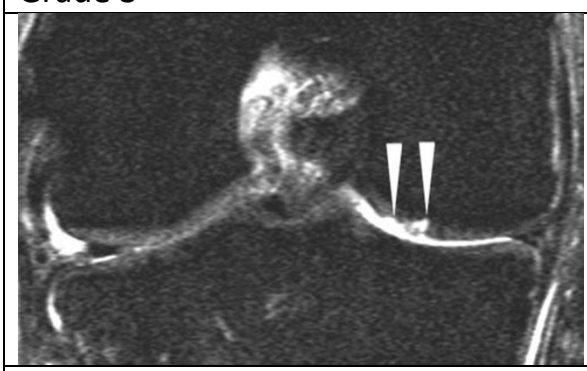
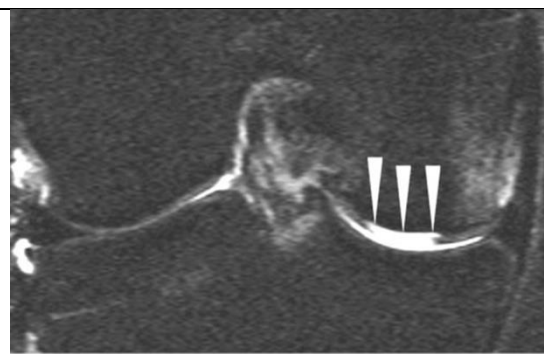
- Well defined rounded areas of fluid signal intensity.
- They may contain necrotic bone debris, myxoid and adipose tissue, fibrous elements, or proteinaceous material and are lined by nonepithelial fibrous wall.

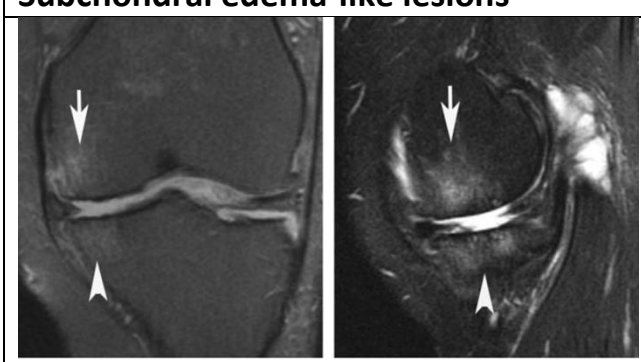
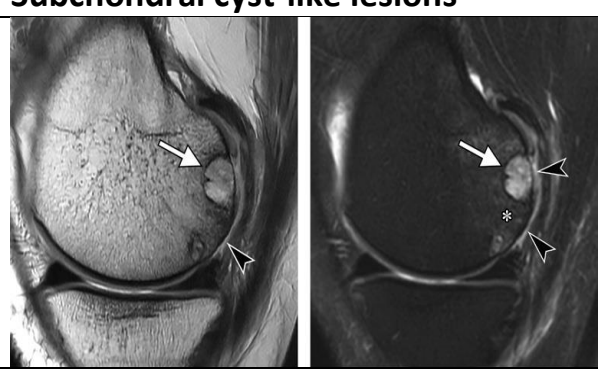
Subchondral sclerosis

- Subchondral low-signal-intensity areas
- Related to a deposition of new bone on preexisting trabeculae and to trabecular compression and microfractures with callus formation.

Grade 1	Grade 2	Grade 3	Grade 4
			

Grade 1	Grade 2
	

Grade 3	Grade 4
	

Subchondral edema-like lesions	Subchondral cyst-like lesions
	

B- Osteochondral Fractures

Bone bruises or contusion:

- Trabecular microfractures
- MRI: ill-defined bone marrow edema
- NO contour abnormalities or discrete fracture line

Chondral Fracture:

- Cartilage injury may consist purely of cartilage.

Subchondral Fracture:

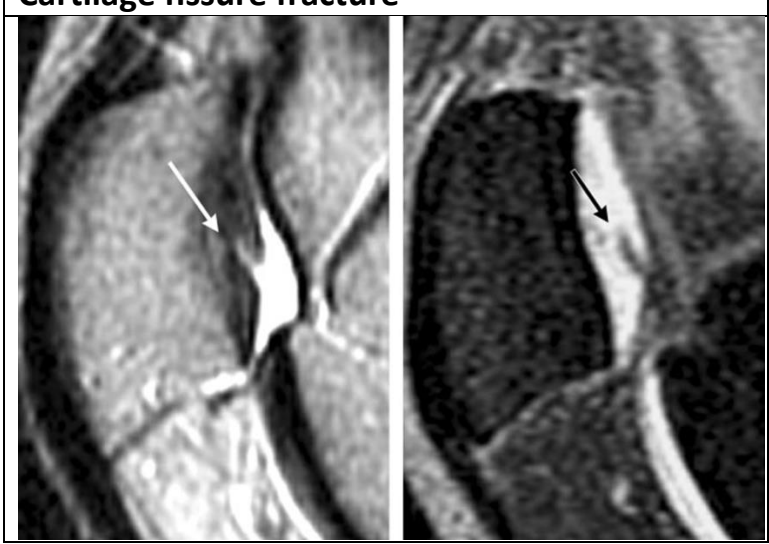
- Subchondral fracture linear hypointensity on T1 and T2
- NO associated contour deformity
- NO visible involvement of the articular surface

Osteochondral Fracture:

- Involve both articular cartilage and the subchondral bone plate.
- A curvilinear fracture may completely encircle a portion of the subchondral bone and the overlying cartilage, creating an osteochondral fragment.

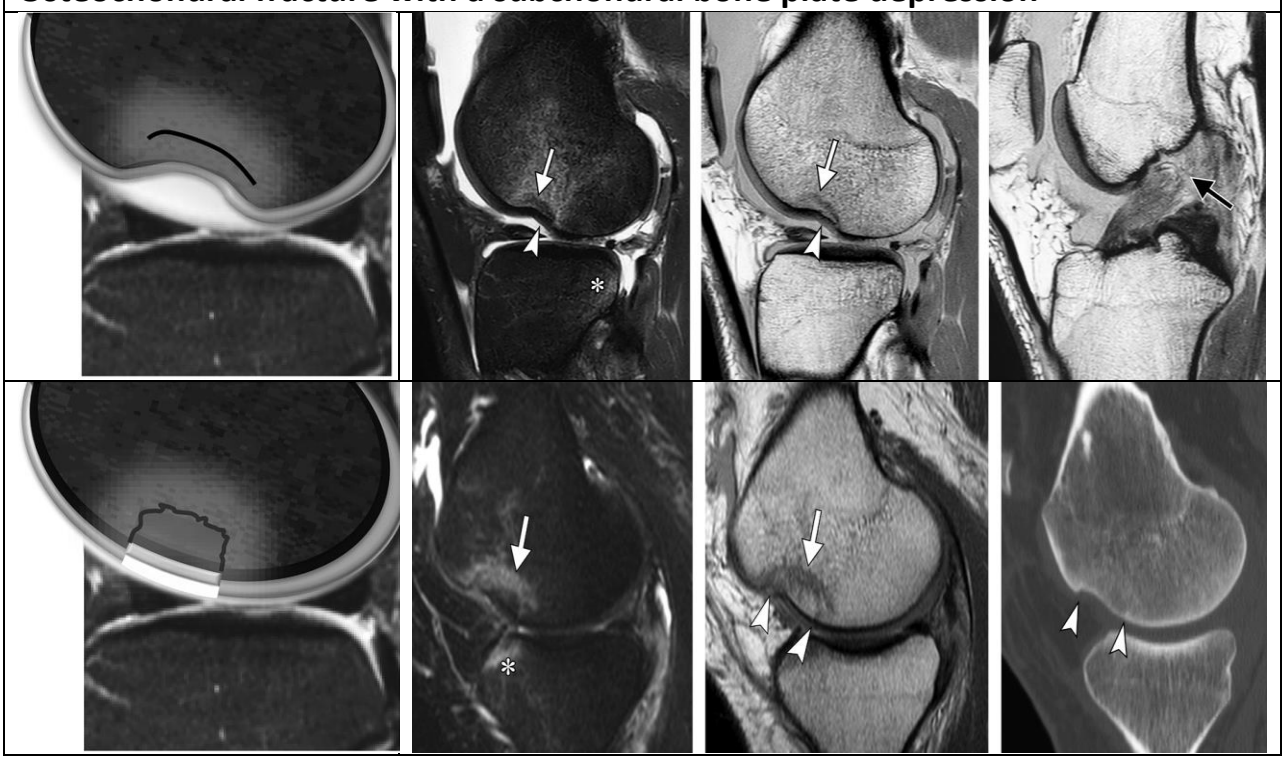
Stages:

1) Injury limited to articular cartilage
2) Cartilage injury with associated subchondral fracture
3) High signal around osteochondral fracture (rim sign) but not displaced
4) Osteochondral fragment displaced
5) Subchondral cyst formation

Cartilage fissure fracture	Cartilage delaminated
	

Subchondral fracture

Osteochondral fracture with a subchondral bone plate depression



C- Osteochondritis Dissecans

- Osteochondritis dessicans, also known as osteochondral fracture and osteochondral defect, is a form of osteochondrosis of the articular cartilage in the epiphyses.
- Refers to a focal area of subchondral bone that undergoes necrosis.
- The overlying cartilage remains intact to variable degrees, receiving nourishment from the synovial fluid.
- Most common cause of an intra-articular loose body
- The condition can manifest either in childhood (juvenile OCD) or middle age (adult OCD)
- Atheletic.
- M > F

- Repetitive microtrauma applied to cartilage and subchondral bone.
- Segmental avascular necrosis of the subchondral bone.
- Sequestrated necrotic osteochondral fragment (= Subchondral bone + overlying cartilage)

Most Common Sites:

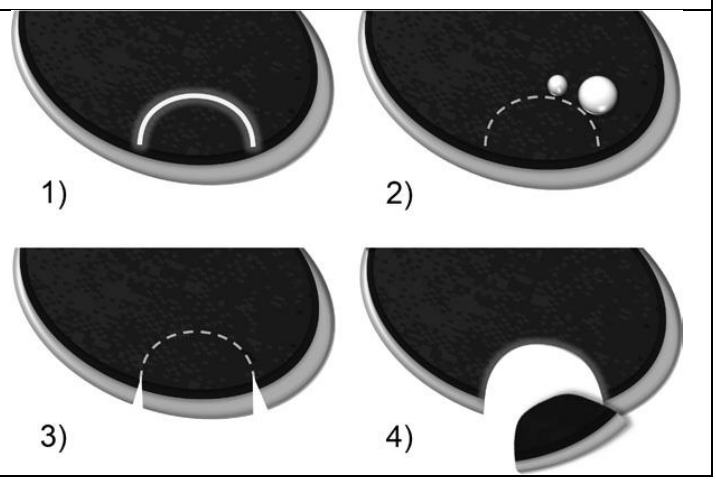
- Knee:
    - Medial femoral condyle: non-weight-bearing Lateral aspect (Most common site)
    - Medial femoral condyle: weight-bearing surface (10%)
    - Lateral femoral condyle: Inferior aspect
    - Patella: Medial facet
- Ankle:
    - Talar dome: Medial > Lateral aspect
- Feet:
    - Head of 1st metatarsal
- Shoulder:
    - Humeral head
- Elbow:
    - Capitellum
- Wrist:
    - Scaphoid

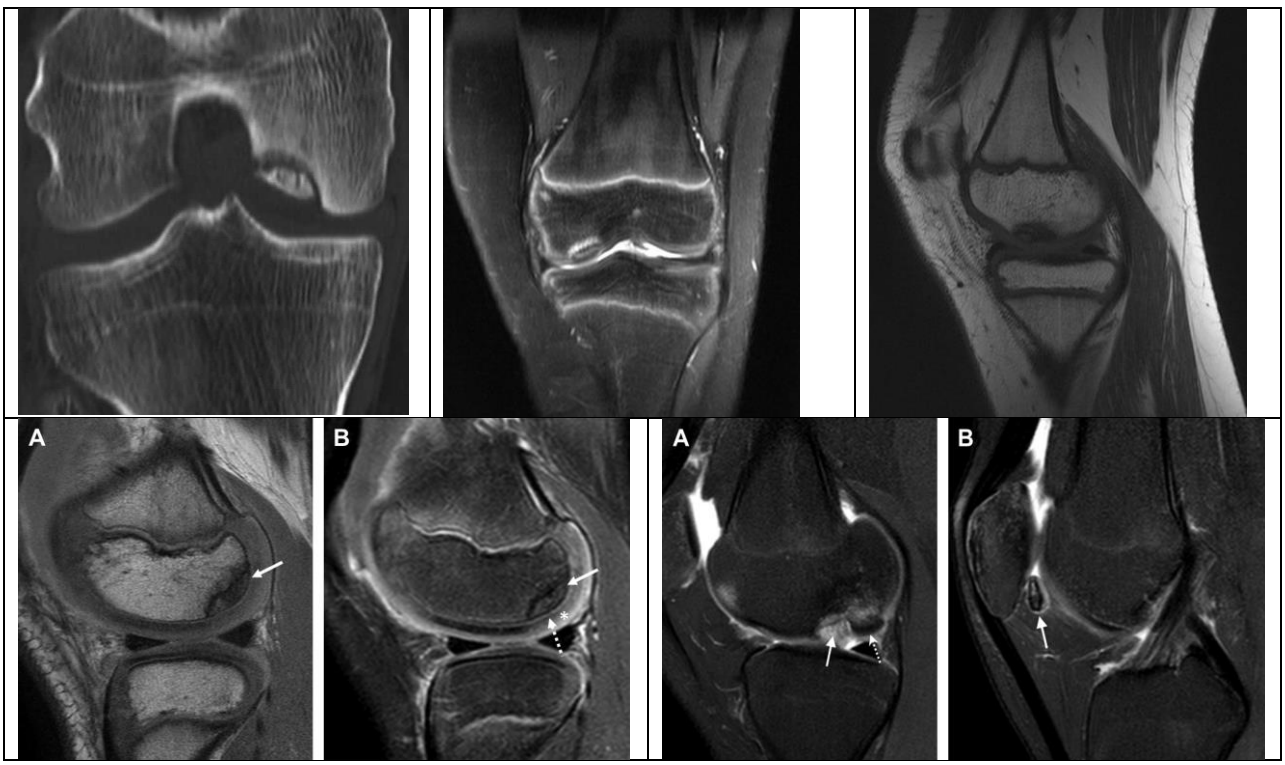
MRI Staging

- Stage I: Thickening of articular cartilage and low signal changes (stable)
- Stage II: Articular cartilage breached, low-signal rim behind fragment indicating fibrous attachment (stable)
- Stage III: Articular cartilage breached, high-signal changes behind fragment and underlying subchondral bone (unstable; but not dislocated)
- Stage IV: Loose body (unstable and dislocated)

❖ Classic four signs of instability in an OCD lesion

1) High signal rim at the interface between the fragment and the adjacent bone on T2
2) Fluid-filled cysts beneath the lesion
3) High-signal line extending through the articular cartilage overlying the lesion
4) Focal osteochondral defect filled with joint fluid.





D-Spontaneous Osteonecrosis of knee (SONK) Subchondral Insufficiency Fracture (SIF)

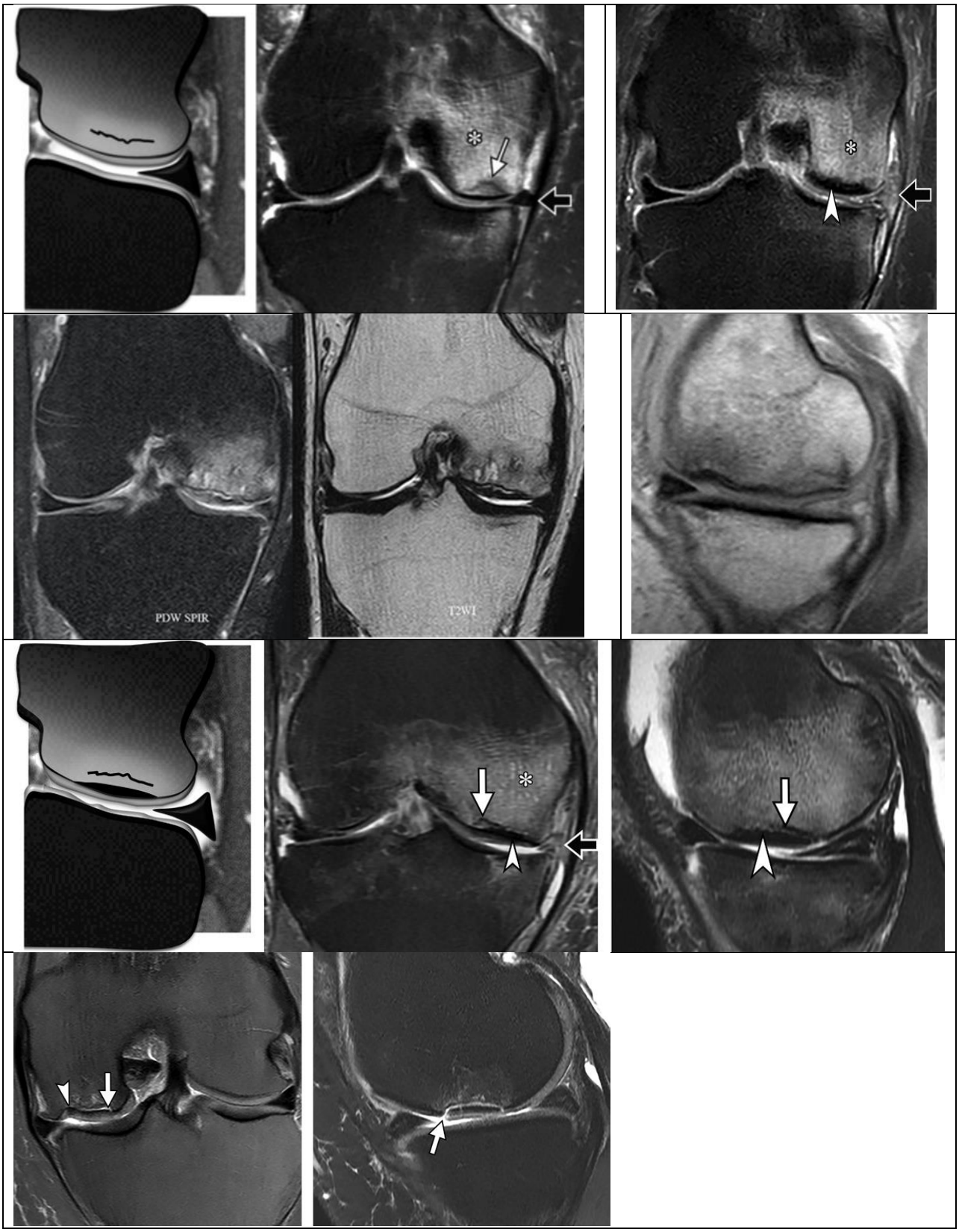
- SONK has similar appearances to osteochondritis dissecans of the knee but is found in an older age group.
- No predisposing factors. However, by definition, secondary osteonecrosis of the knee occurs secondary to an insult.
- F>>M = 3:1
- Age > 55y.

Radiographic features

- It is almost always unilateral.
- Usually affects the weight bearing portion of the medial femoral condyle.
- Subchondral lucency in the medial femoral condyle => BM edema
- Flattening of the medial femoral condyle.
- A narrow zone of increased radiodensity adjacent to the depressed osseous surface.

MRI Findings:

- Marked bone marrow edema emanating from the subchondral region and extending over large areas often involving the entire femoral condyle.
- Subchondral hypointense line that is irregular, curvilinear or parallel to the subchondral bone plate
- An area of low signal intensity immediately subjacent to and creating the appearance of a thickened subchondral bone plate.
- Deformity of the subchondral bone plate defined as either subtle flattening or a focal depression that represents a subchondral bone plate fracture.
- Fluid-filled cleft underlying subchondral bone plate, indicating its gross collapse and separation.


PDW SPIR
T2WI

E- Primary Osteonecrosis (AVN)

Table 1: Causes of ON

Common
Trauma
Corticosteroids (exogenous and endogenous)
Idiopathic
Sickle cell anemia
Collagen vascular disease
Alcoholism

Early AVN:

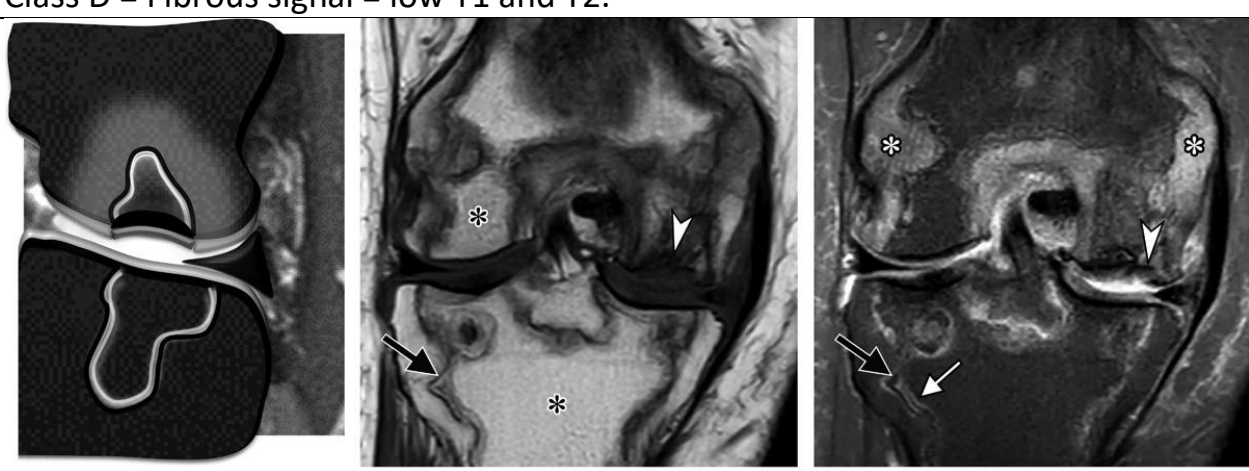
- T2 "double-line sign":
  - An inner high-signal intensity band (vascularized granulation tissue, or the "creeping zone of substitution")
  - An outer low-signal-intensity band (sclerotic appositional new bone).
- T1 Dark band.

Late AVN:

- Subchondral low signal on T1 and T2 WIs
- Articular surface collapse.

Mitchell Classification of the central avascular segment:

Class A = Fat signal = High T1 and intermediate T2.
Class B = Blood signal = High T1 and T2 signal.
Class C = Edema signal = Low T1 and high T2 signal.
Class D = Fibrous signal = low T1 and T2.



a. b. c.

Blount Disease

- Blount disease refers to a local disturbance of growth of the medial aspect of the proximal tibial metaphysis and/or epiphysis that results in tibia vara.

- Early onset: Infantile (1-3Y) – Common – Bilateral.
- Late onset: Juvenile/Adolescent (>4Y) – Infrequent – Unilateral.

Radiological findings:

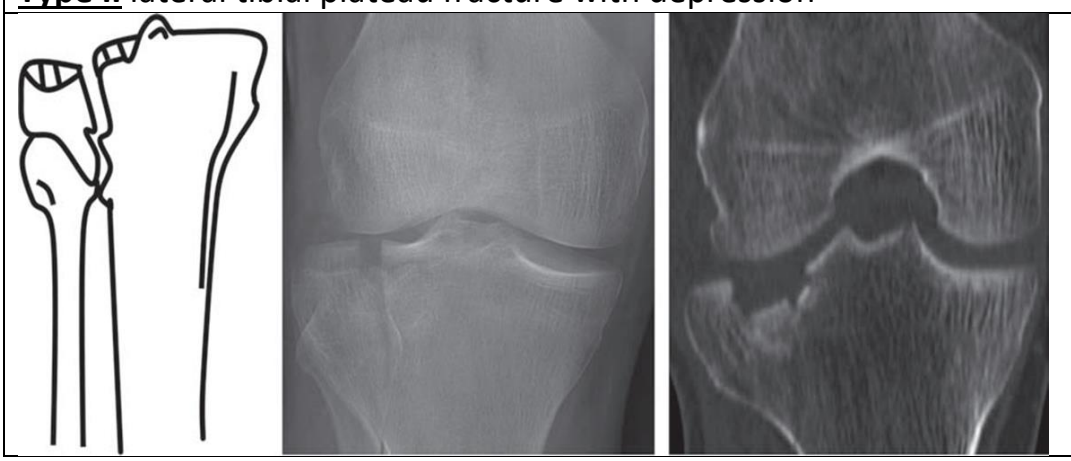
- Fragmental of the medial tibial epiphysis.
- Irregular medial epiphyseal line.
- Beaking of the medial tibial metaphysis.
- Genu varus deformity.

Schatzker Tibial Plateau Fracture Types

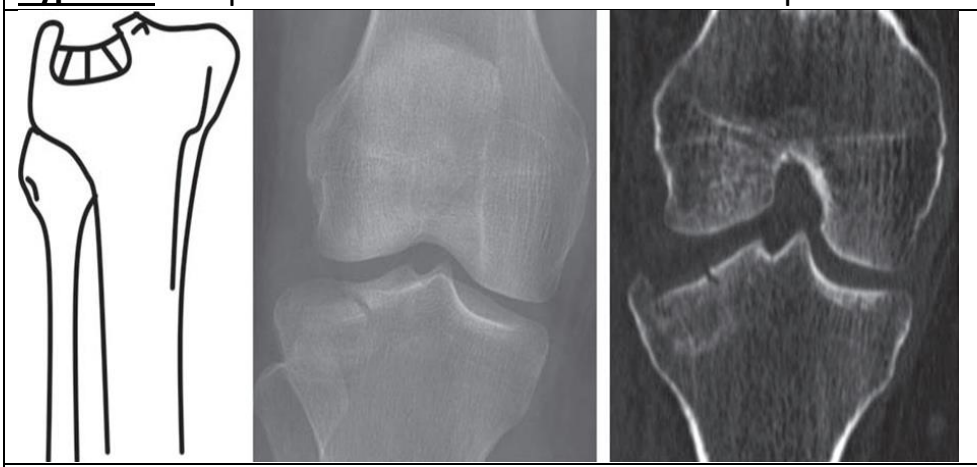
Type I lateral tibial plateau fracture without depression
Type II lateral tibial plateau fracture with depression
Type III compression fracture of the lateral (IIIA) or central (IIIB) tibial plateau
Type IV medial tibial plateau fracture
Type V bicondylar tibial plateau fracture
Type VI tibial plateau fracture with diaphyseal discontinuity

Type I lateral tibial plateau fracture without depression

Type II lateral tibial plateau fracture with depression

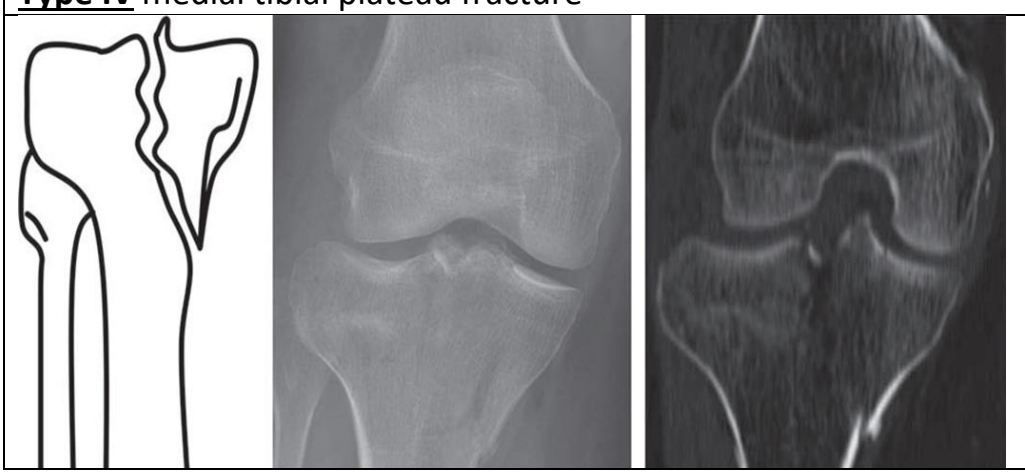


Type IIIA compression fracture of the lateral tibial plateau

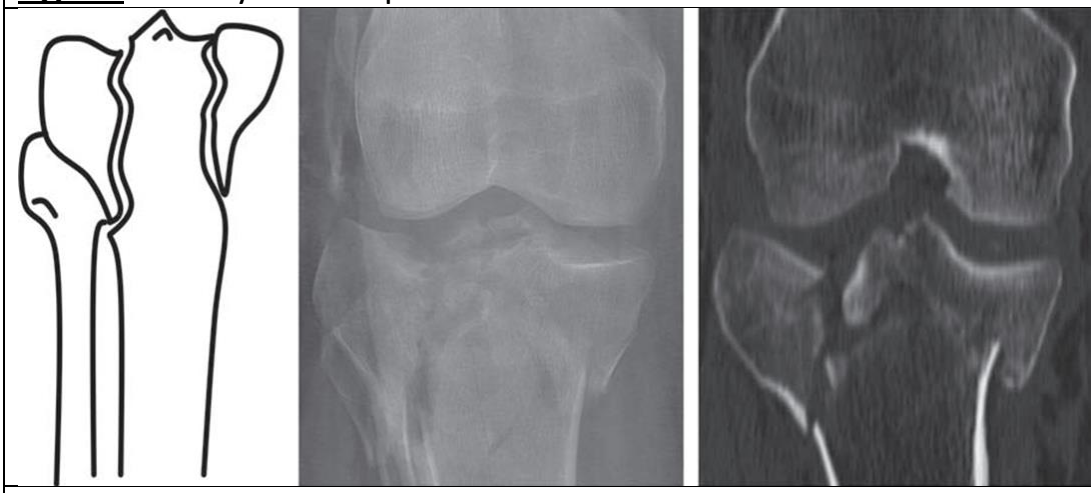


Type IIIB compression fracture of the central tibial plateau

Type IV medial tibial plateau fracture



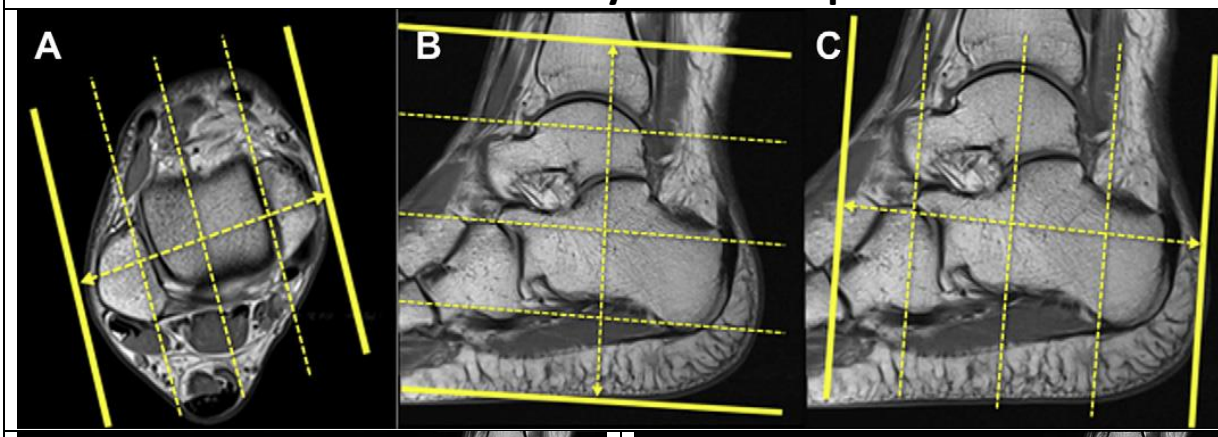
Type V bicondylar tibial plateau fracture

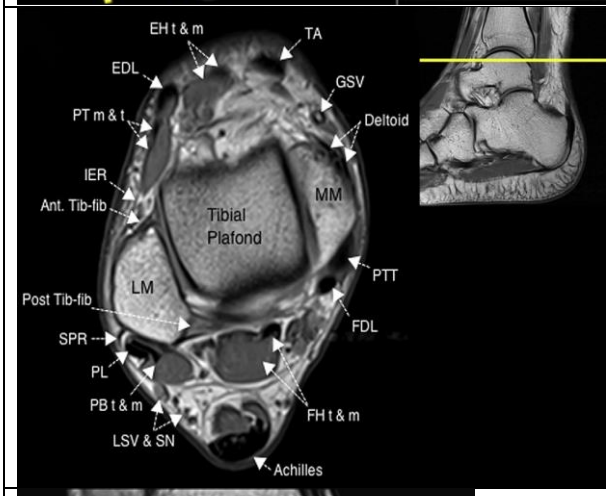


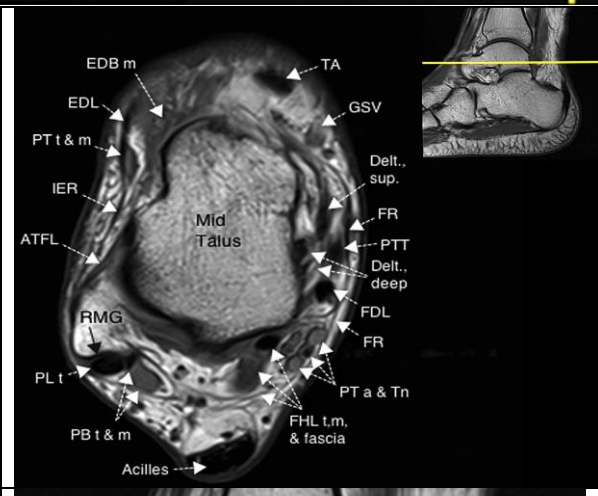
Type VI tibial plateau fracture with diaphyseal discontinuity

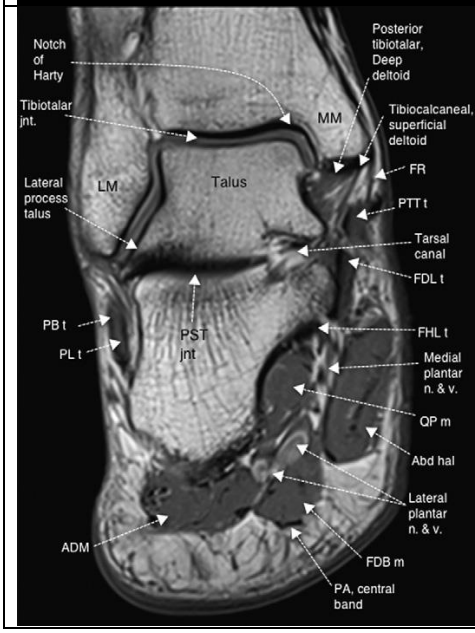
Ankle Joint

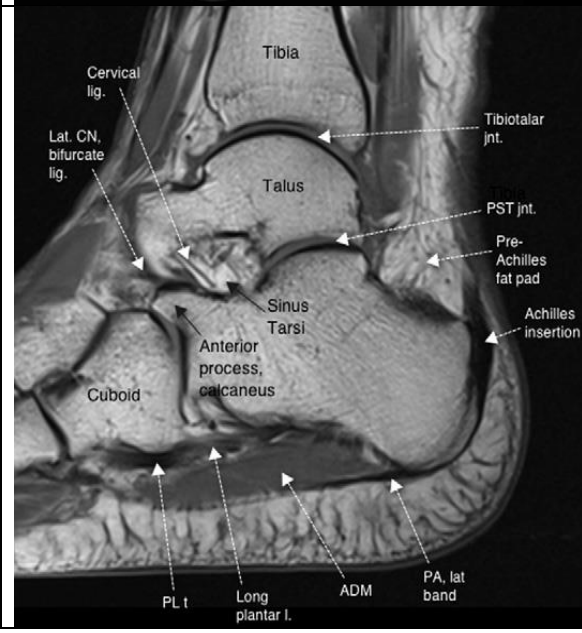
MRI Anatomy & Technique

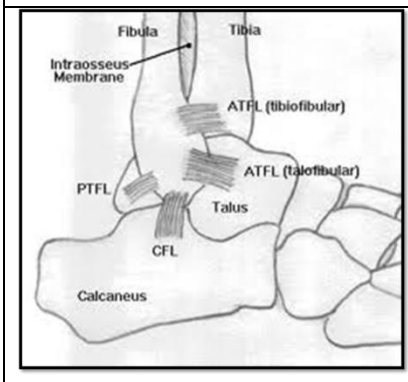
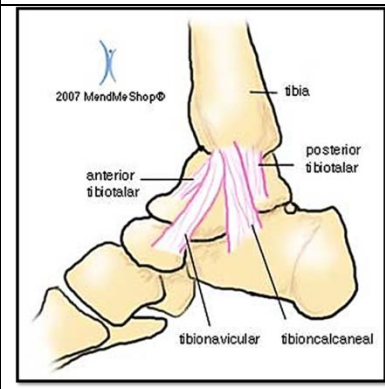


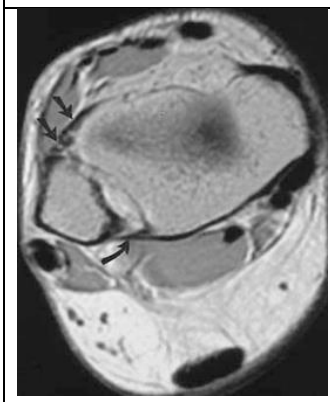
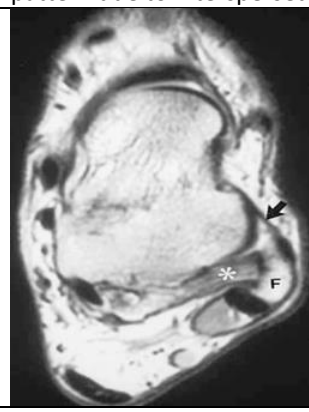
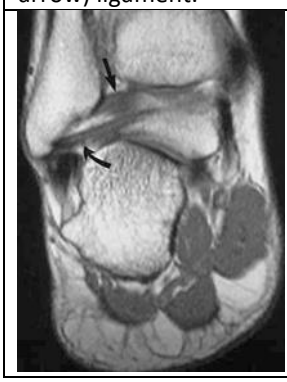








❖ **Lateral Collateral Ligament Complex**	❖ **Medial Collateral Ligament Complex = Deltoid Ligament**
Anterior Tibio-fibular. Posterior Tibio-fibular. Anterior Talo-fibular Posterior Talo-fibular. Calcaneo-fibular.	Anterior tibio-talar. Posterior tibio-talar. Tibio-navicular. Tibio-calcaneal.
	

Axial T1-WI at the joint level shows:	**Axial T1-WI at malleolar fossa shows:**	**Axial T1-WI shows:**
Anterior (straight arrows) tibiofibular ligaments Posterior (curved arrow) tibiofibular ligaments.	Anterior talofibular ligament (arrow). Posterior talofibular ligament normally demonstrates a striated pattern due to interspersed fat (*).	Calcaneofibular ligament (straight arrows) immediately adjacent to the peroneal tendons (curved arrow).
		
Coronal T1-WI shows: Posterior tibiofibular (straight arrow) ligament. Posterior talofibular (curved arrow) ligament.	Coronal T1-WI shows: Striated posterior tibiotalar (*) and Tibiocalcaneal (arrow) bands of deltoid ligament.	
		

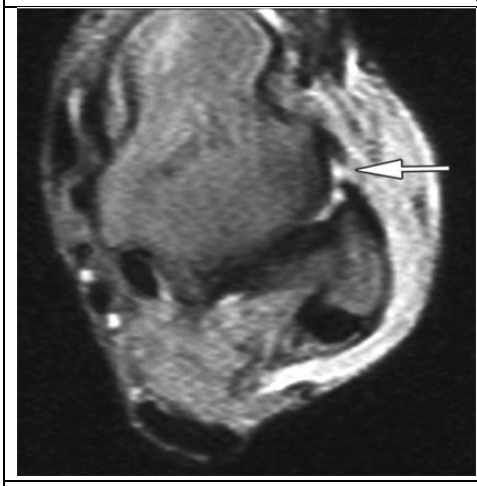
Ligamentous Injuries

- Lateral ankle sprains represent 16%–21% of sports-related traumatic lesions.
- The anterior talofibular ligament is the weakest ligament and therefore the most frequently torn.

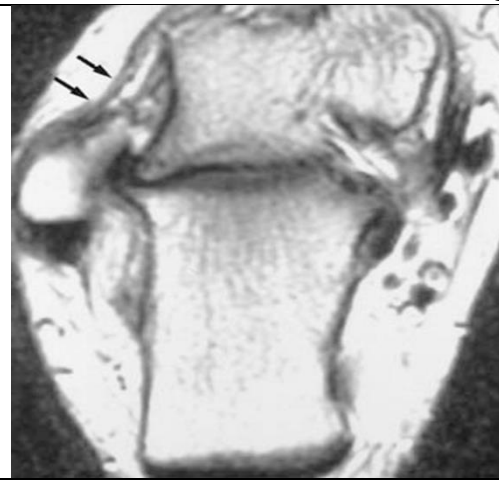
Anatomic classification of ankle sprains is based on the number of affected ligaments:

- **1st degree sprain**: Partial or complete tear of anterior talofibular ligament.
- **2nd degree sprain:** Partial or complete tear of both anterior talofibular and calcaneofibular ligaments.
- **3rd degree sprain**: injuries to the anterior talofibular, calcaneofibular, and posterior talofibular ligaments.

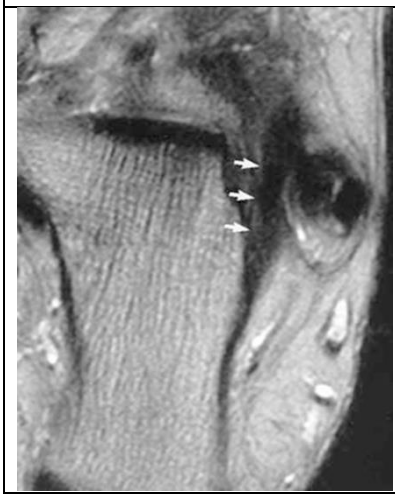
Acute tear of anterior talofibular ligament



Chronic tear of anterior talofibular ligament



Chronic tear of calcaneofibular ligament



Injury of Deltoid ligament

Tendon Injuries

A- Achilles Tendon Injuries

❖ Achilles peritendinosis:

- Linear or irregular areas of altered signal intensity in the pre–Achilles tendon fat pad, a finding that indicates the presence of edema or scarring of the peritenon.
- The tendon itself is normal.
- The Achilles tendon lacks a tendon sheath.

❖ Insertional tendinosis:

- Increased signal and thickening at the insertion site of the Achilles tendon,
- Intra-substance calcifications.
- Prominent posterosuperior calcaneal tuberosity (Haglund deformity)
- Calcaneal marrow edema
- Retrocalcaneal and Achilles bursitis

❖ Partial Achilles Tendon Tear

Heterogeneous signal intensity and thickening of the tendon without complete interruption.

❖ Complete Achilles Tendon Rupture

Fraying and retraction of torn edges of tendon.
Tendon gap filled with edema and haemorrhage.

❖ Achilles Tendon Xanthomas

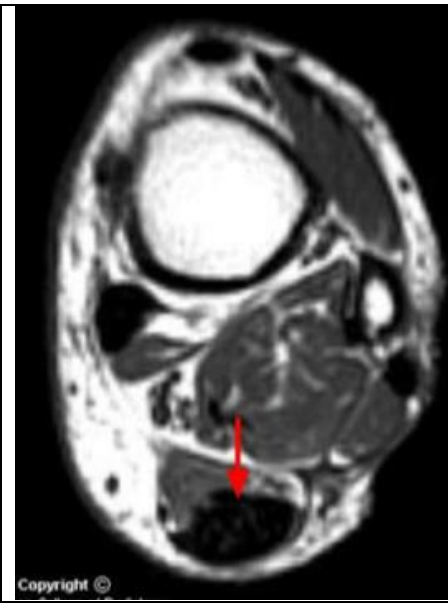
- Achilles tendon xanthomas occur in less than 50% of patients with familial hypercholesterolemia.

Location:

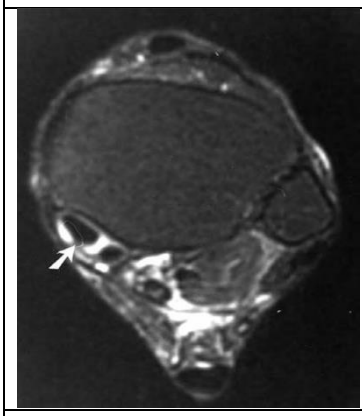
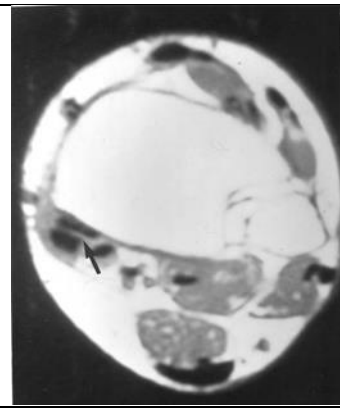
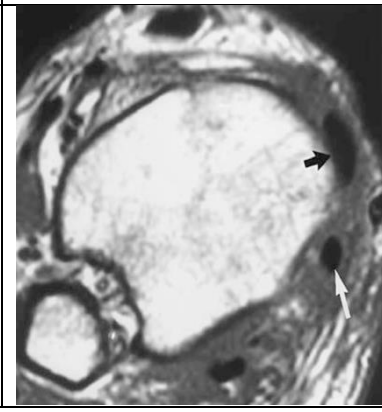
- Finger extensors in the dorsum of the hands
- Achilles tendons distal third near their insertion on the calcanei
- Plantar fascia is occasionally infiltrated
- Extensor tendons of the toes are more rarely involved

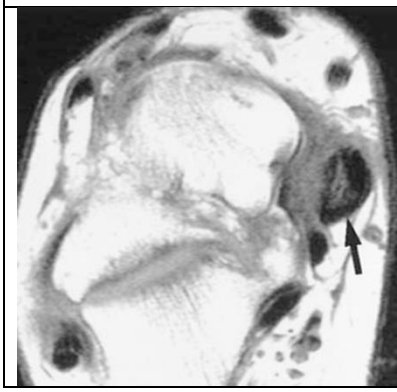
Imaging Findings:

- Painless nodular masses
- The anterior (ventral) surface is typically convex (normally concave or flat) in the axial view.
- AP thickness > 7mm in men and > 6 mm in women
- Fusiform tendinous or aponeurotic enlargement
- Heterogeneous signal intensity
- Small foci of increased signal intensity corresponding to the xanthomatous deposits, along with trabeculated low signal- intensity areas representing the remaining tendinous fascicles, produce a characteristic speckled or reticulated appearance on both T1- and T2-weighted images



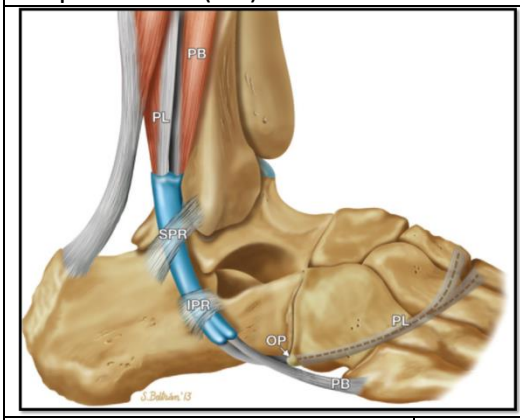
B- Posterior Tibial Tendon

❖ Tenosynovitis	❖ Longitudinal Split Tear	❖ Dislocation of posterior tibial tendon
• Fluid is seen within the tendon sheath	"two posterior tibial tendons."	The tendon is seen medial or anterior to the medial malleolus (black arrow). Avulsed or stripped flexor retinaculum
		

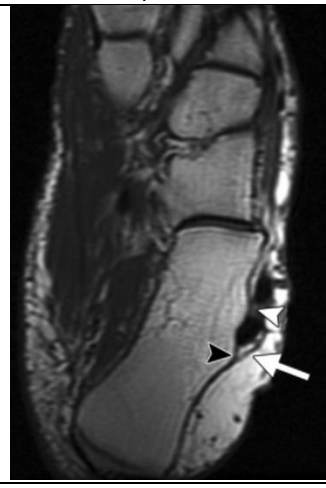
❖ Partial Tear	❖ Complete tear
Fusiform enlargement High-signal-intensity within the substance of the tendon	• Absence of the posterior tibial tendon • The tibial retromalleolar groove has been replaced by synovial fluid and debris (arrow).
	

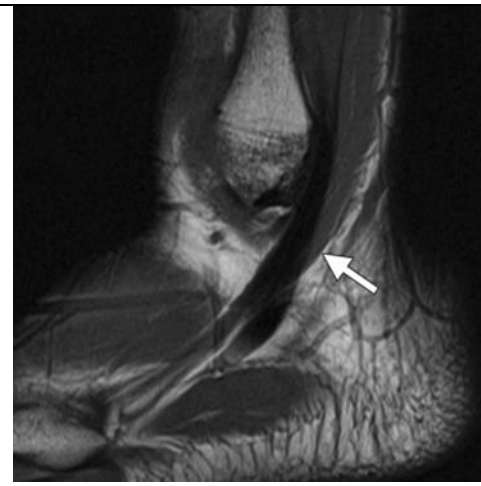
C- Peroneal Tendons

PB = peroneus brevis
PL = peroneus longus
SPR= superior peroneal retanuclum
IPR = inferior peroneal retinaculum
Os peroneum (OP)

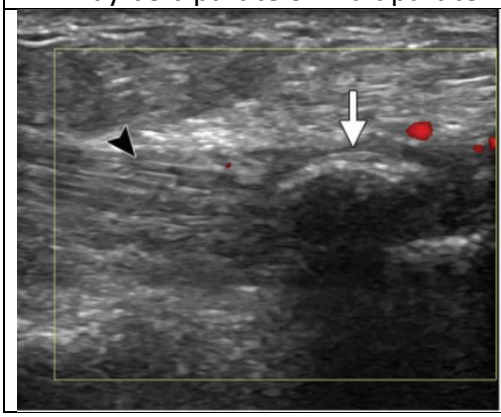
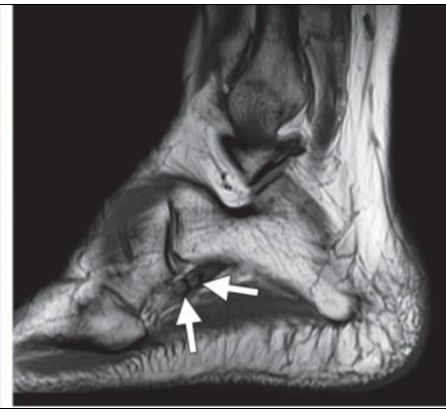


<u>Sagittal:</u>
Peroneal tendons at the lateral aspect of the foot
PB tendon (arrow) located superior to the PL tendon (arrowhead).

Axial at Fibular Retromalleolar Groove:	**Axial at Lateral Aspect Of Hindfoot:**	**Axial at Plantar aspect of foot:**
PB tendon (black arrow) medial, crescentic, boomerang-shaped. PL tendon (black arrowhead) Lateral. SPR = superior peroneal retinaculum (white arrow) is superficial to the peroneal tendons.	PB tendon anterior PL tendon posterior. IPR = inferior peroneal retinaculum (white arrow) is superficial to the peroneal tendons and attaches onto the retrotrochlear eminence. Peroneal tubercle is more anterior (white arrowhead), Retrotrochlear eminence is more posterior (black arrowhead)	PL tendon in the cuboid tunnel (black arrow) PL tendon along the plantar aspect of the foot (arrowhead).
		

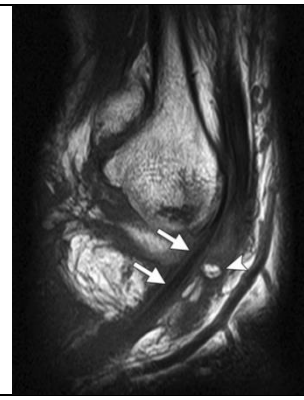
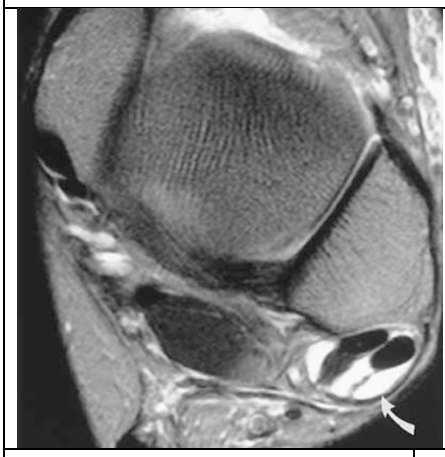
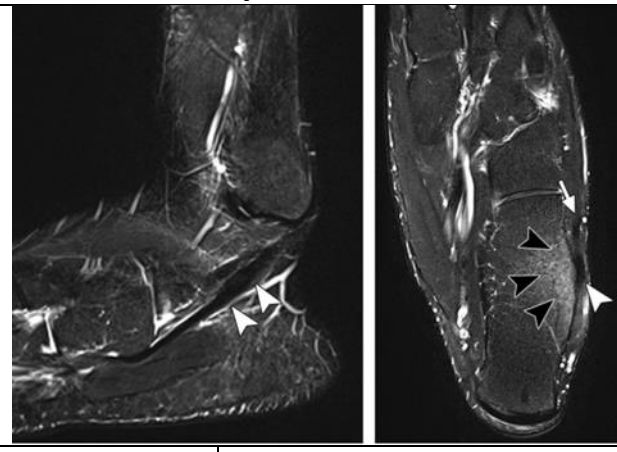
Enlarged Retrotrochlear Eminence & Peroneal Tubercle Double-headed arrow > 5 mm	Low-lying PB muscle belly (arrow) posterior to the peroneal tendons
	
Os Peroneum	

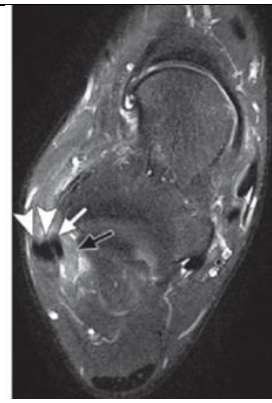
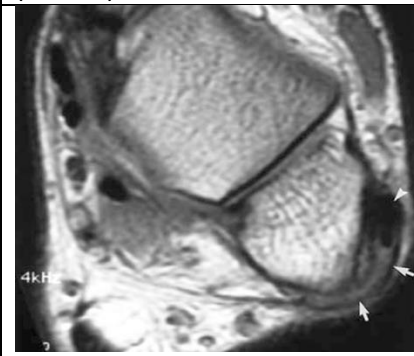
- A sesamoid bone within the PL tendon
- is located in the region of the cuboid tunnel at the lateral aspect of the cuboid bone.
- may be cartilaginous or ossified
- may be bipartite or multipartite

✓ Painful Os Peroneum:

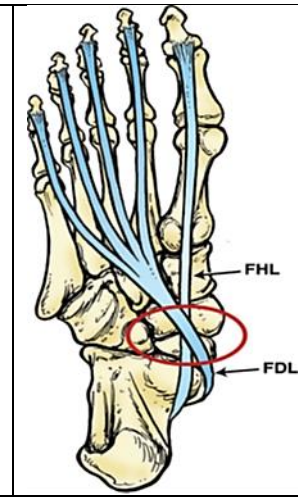
- **Os peroneum fracture**
- **Diastasis of a bipartite or multipartite os peroneum**
- **PL tenosynovitis**
- **PL thickness tear**
- **PL longitudinal split tears**
- **PL tendon rupture**
- **Dislocation of Peroneal Tendons.**

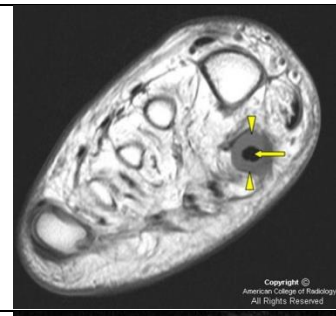
❖ Fractured Os Peroneum	❖ Torn PL and retracted os peroneum
	
❖ Peroneal tenosynovitis:	**❖ PL tendonopathy at lateral aspect of calcaneus**
	

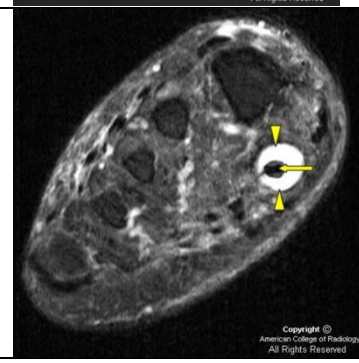
❖ PB Longitudinal split tear:	❖ PL Longitudinal split tear	❖ Dislocation of Peroneal Tendons:
Axial PD WI shows a C-shaped split peroneus brevis tendon (white arrow) partially enveloping the peroneus longus tendon (black arrow).	Axial PD WI shows 2 hemitendons (arrow heads)	Axial PD WI shows the dislocated peroneus brevis and longus tendons (arrowhead) within a “pouch” formed by the stripped-off superior peroneal retinaculum (arrows).
		

D-Flexor Hallucis Longus Tendon:

- FHL tenosynovitis develops from repeated plantar flexion of the foot, particularly in ballet dancers, basketball players, and runners.
- FHL tenosynovitis often occurs at two characteristic locations:
    - Proximal tenosynovitis: At the ankle, where it becomes trapped between the posterior malleolus of the tibia and calcaneus
    - Distal tenosynovitis: in the distal foot as it passes between the hallux sesamoid bones.

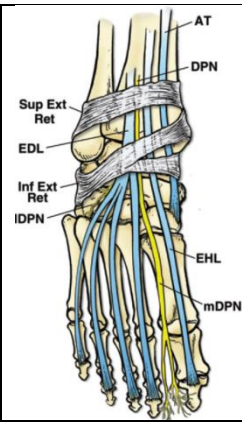


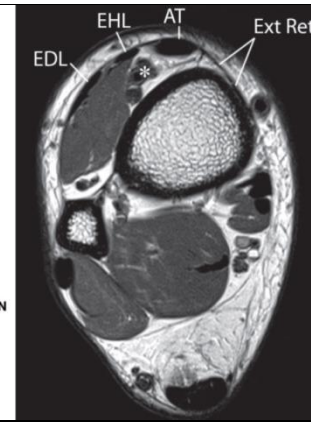




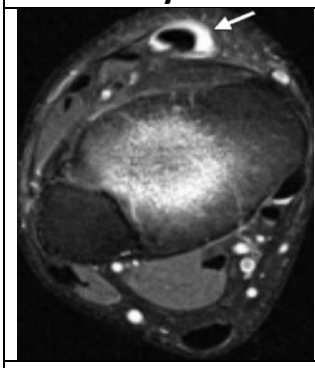
E- Extensor Compartment

AT = Anterior Tibialis
EHL = Extensor Halluces longus
EDL = Extensor Digitorum Longus
* = Anterior Tarsal Tunnel = contains Deep peroneal nerve (DPN) and its branches (Medial and lateral) as they pass deep to the EHL and EDL tendons

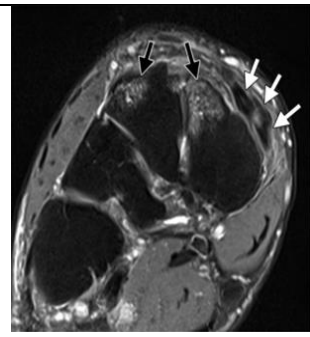




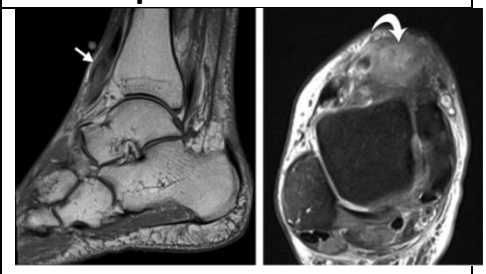
AT Tenosynovitis



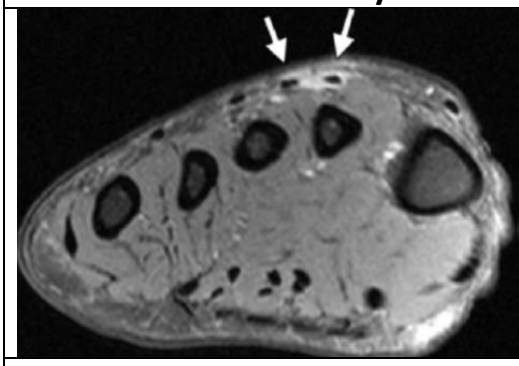
AT Tendinosis



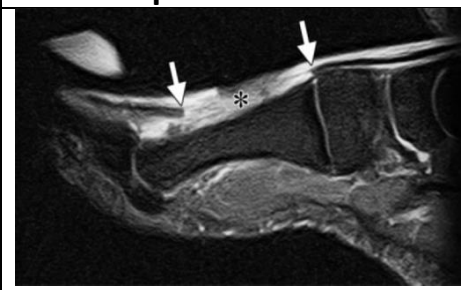
AT Complete Tear



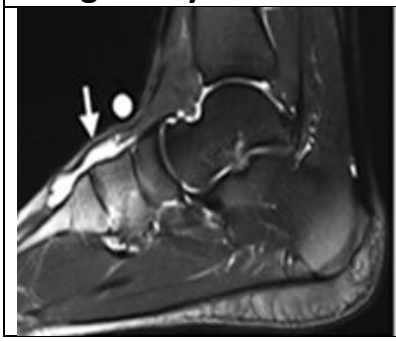
2nd and 3rd EDL Tenosynovitis



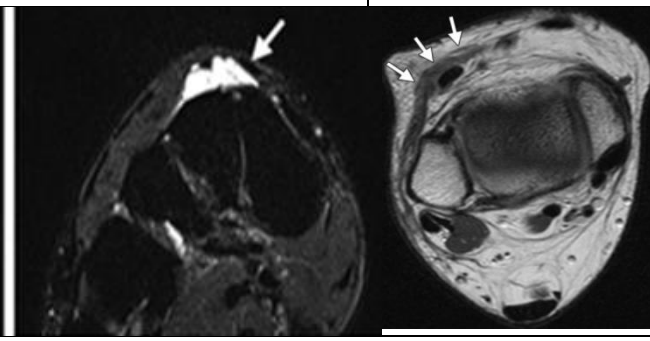
EHL Complete Tear



Ganglion Cyst



Extensor Retinaculum Injury

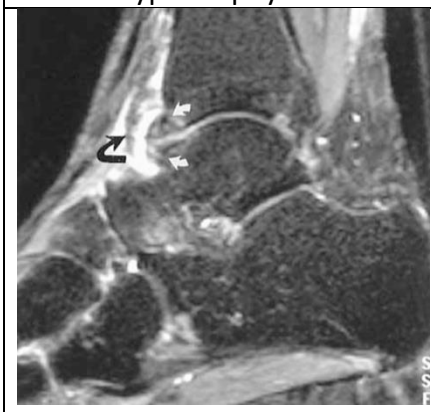
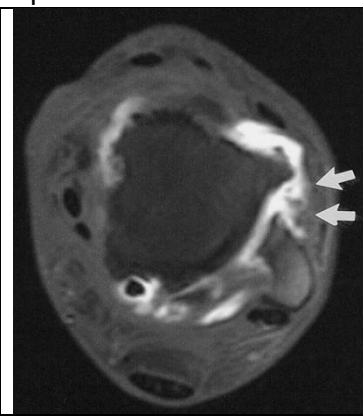
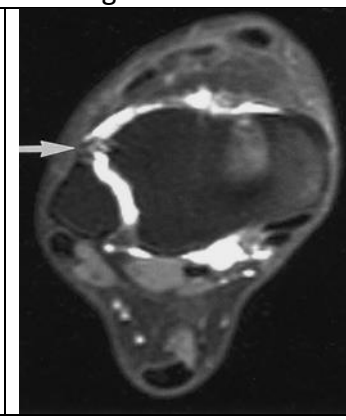


Ankle Impingement Syndromes

A- Anterolateral Impingement Syndrome

Repeated Minor trauma = forced ankle plantar flexion + supination.

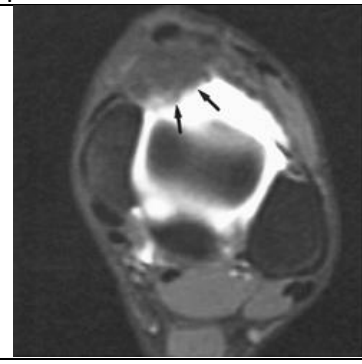
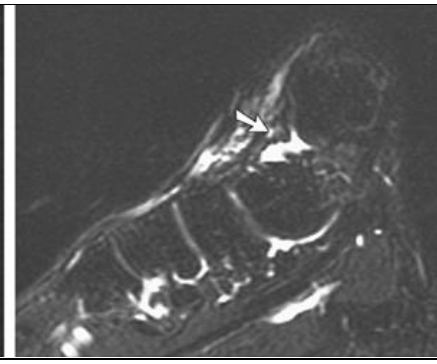
- Tear of the anterolateral soft tissues
- Tear of anterior talofibular and tibiofibular ligaments.
- Soft-tissue hemorrhage.
- Synovial scarring, inflammation, and hypertrophy in the anterolateral recess of the tibiotalar joint.
- Soft-tissue impingement.
- Anterior tibial and talar "kissing" osteophytes
- Hypertrophy of the inferior portion of the anterior tibiofibular ligament

B- Anteromedial Impingement

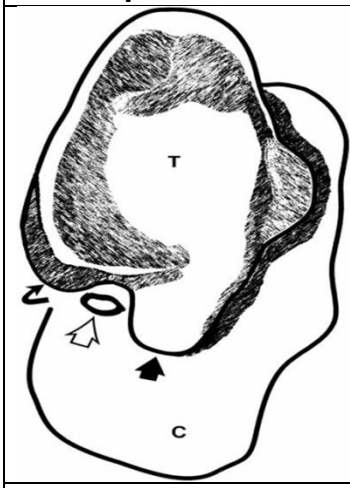
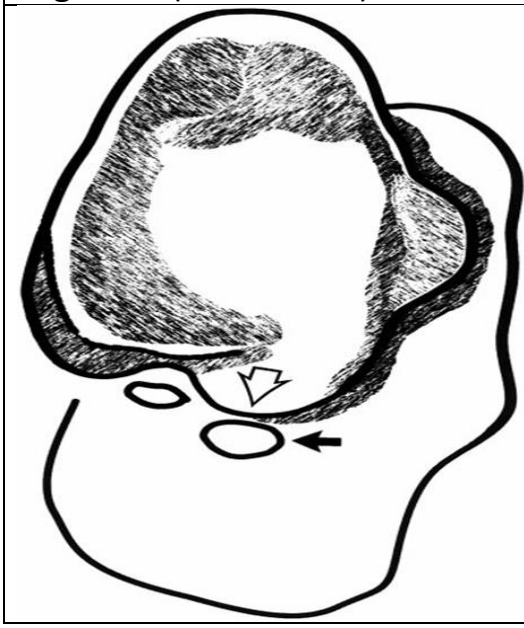
Repeated Minor trauma or forced ankle pronation (eversion).

- Tearing of the tibiotalar ligament and anteromedial capsule.
- Soft-tissue hemorrhage.
- Synovial and capsular thickening.
- Synovial scarring.
- Soft-tissue impingement.
- Anteromedial tibitalar spurs.

C- Posterior Impingement (Os Trigonum Syndrome)

❖ Bony Structures of the impingement

FHL tendon (white arrow) in the groove between medial (curved arrow) and lateral talar tubercles (straight black arrow). Large lateral talar process, called **Stieda process**	The posterior malleolus of the tibia (white arrow) may have a more or less pronounced down slope and contribute to the impingement.
	
Short lateral talar tubercle (white arrow) articulating with the **os trigonum** (black arrow).	Prominence of the dorsum of the calcaneal tuberosity (curved arrow)
	

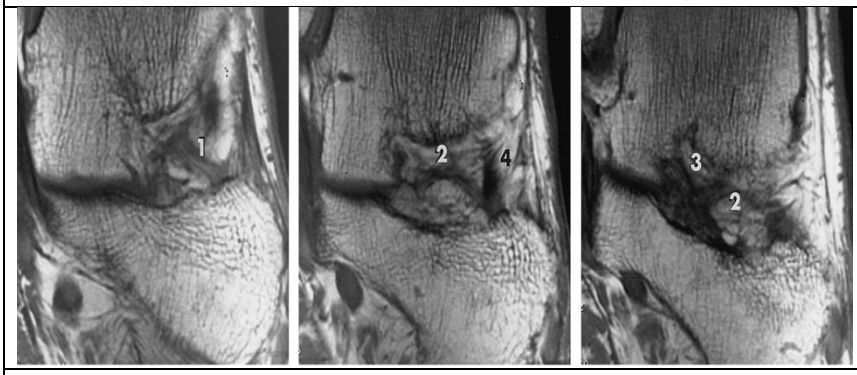
❖ Soft tissue Injures

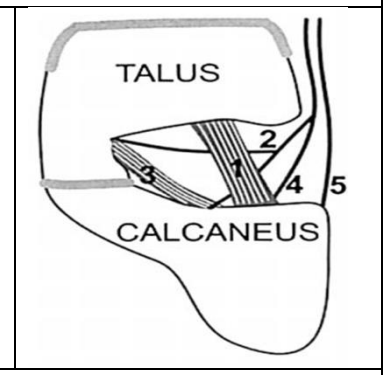
- Inflammatory changes in the posterior ankle soft tissues: The posterior synovial recess of the subtalar and tibiotalar joints and the FHL tendon sheath.
- FHL tenosynovitis

D-Sinus Tarsi Syndrome

Tarsal sinus:

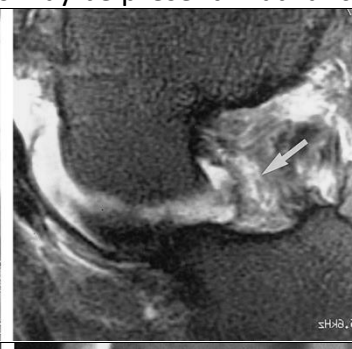
- The sinus tarsi is a fat-filled cone-shaped space that lies between the talus and calcaneus
- Cervical ligament (1)
- Interosseous talocalcaneal ligament (3)
- Medial (2), intermediate (4), and lateral (5) roots of inferior extensor retinaculum.
- Neurovascular structures.

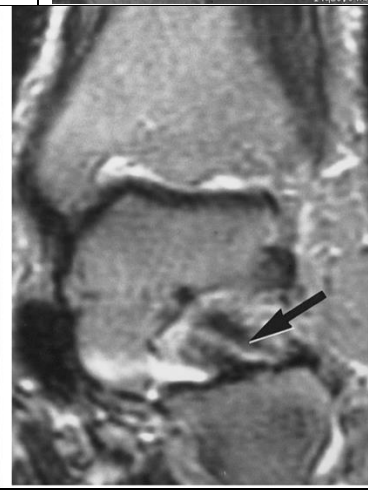


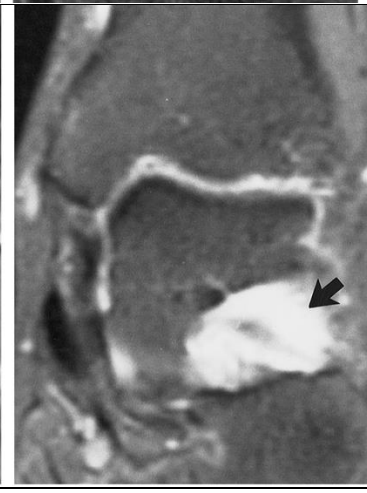


Imaging Findings of sinus tarsi Syndrome:

- Obliteration of fat in the sinus tarsi space.
- Space is replaced by either fluid or scar tissue, and the ligaments may be disrupted.
- Osteoarthritis of subtalar joint and subchondral cysts may be present in advanced cases.







E- Tarsal Tunnel Syndrome

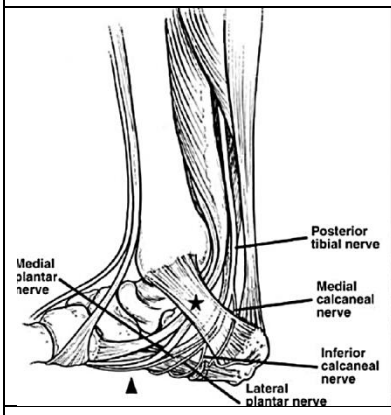
- Pain resulting from compression of posterior tibial nerve as it passes through tarsal tunnel.

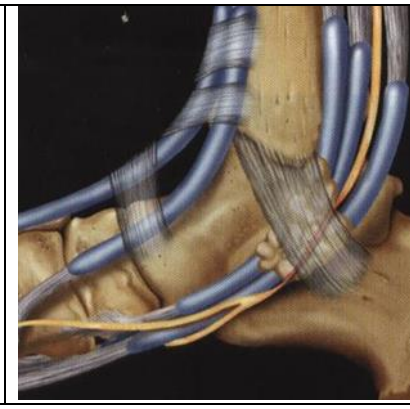
Tarsal tunnel is formed by

- The medial surface of the distal tibia, Talus, Calcaneus,
- The sustentaculum tali
- The flexor retinaculum.

It contains:

The three tendons behind the medial malleolus with the tibial neurovascular bundle.



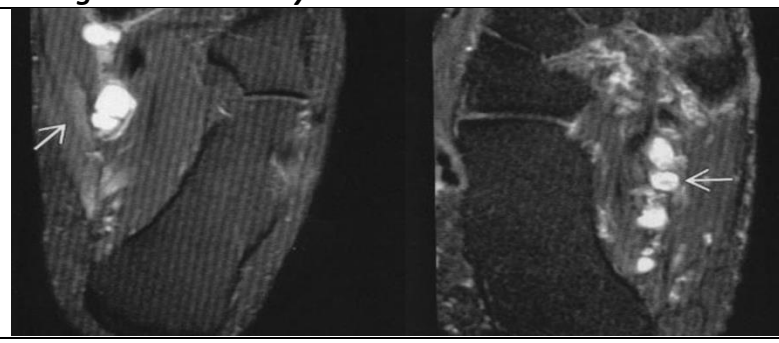


Clinical Picture:

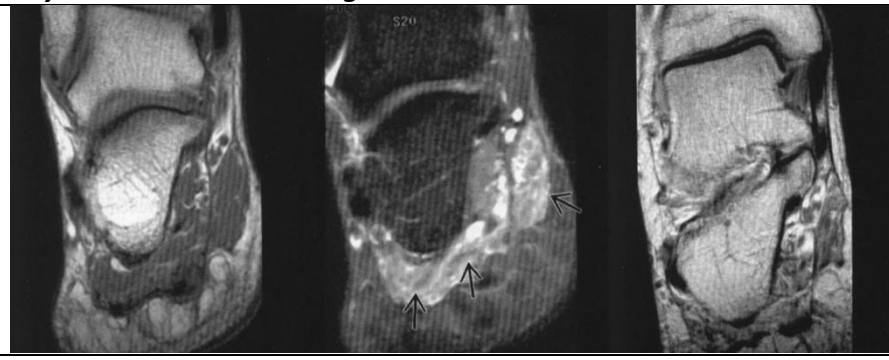
- The patient presents with pain and paresthesia along the medial aspect of the heel and plantar surface of the foot.

D.D.: Plantar fasciitis- Calcaneal bursitis- Tenosynovitis

Varicose veins causing Tarsal tunnel syndrome



Tarsal tunnel syndrome- muscle changes



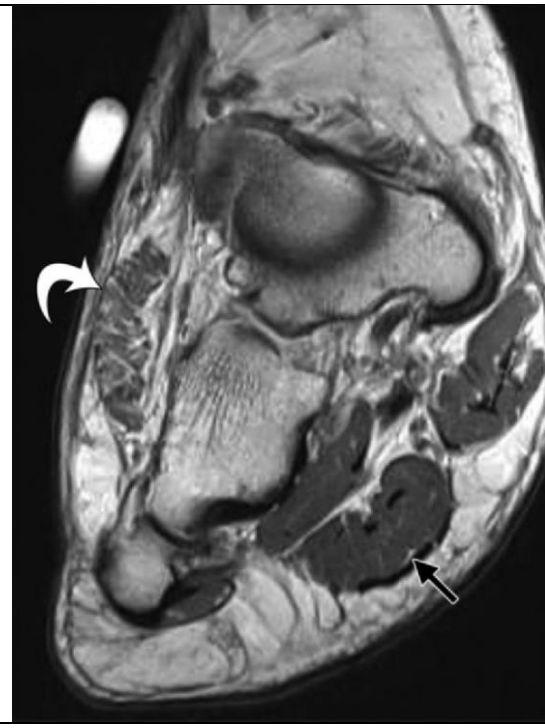
F- Anterior Tarsal Tunnel Syndrome

Entrapment of the Deep Peroneal Nerve (DPN)

=> Denervation atrophy of extensor Digitorum Brevis Muscle:

Decreased size

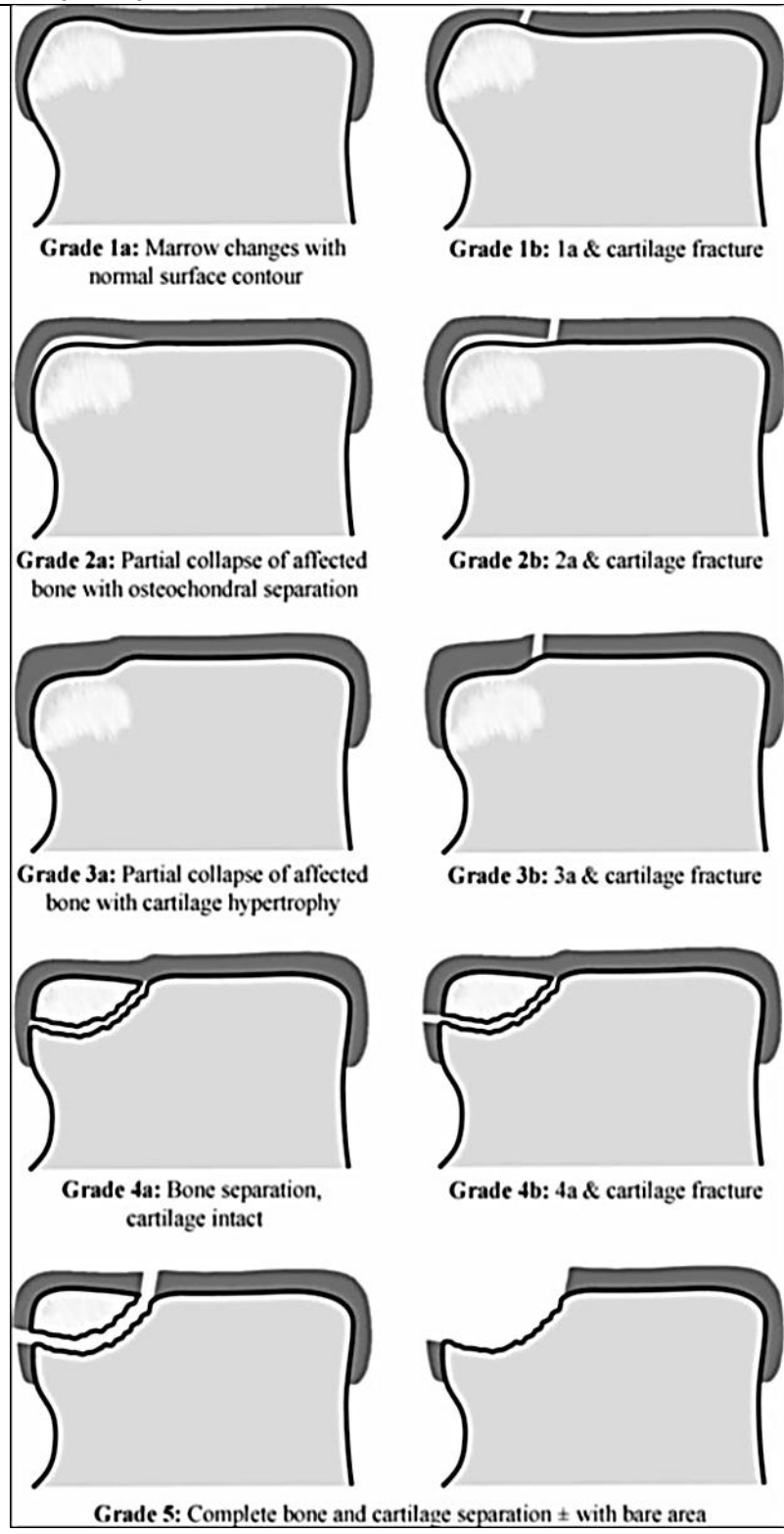
Fatty replacement



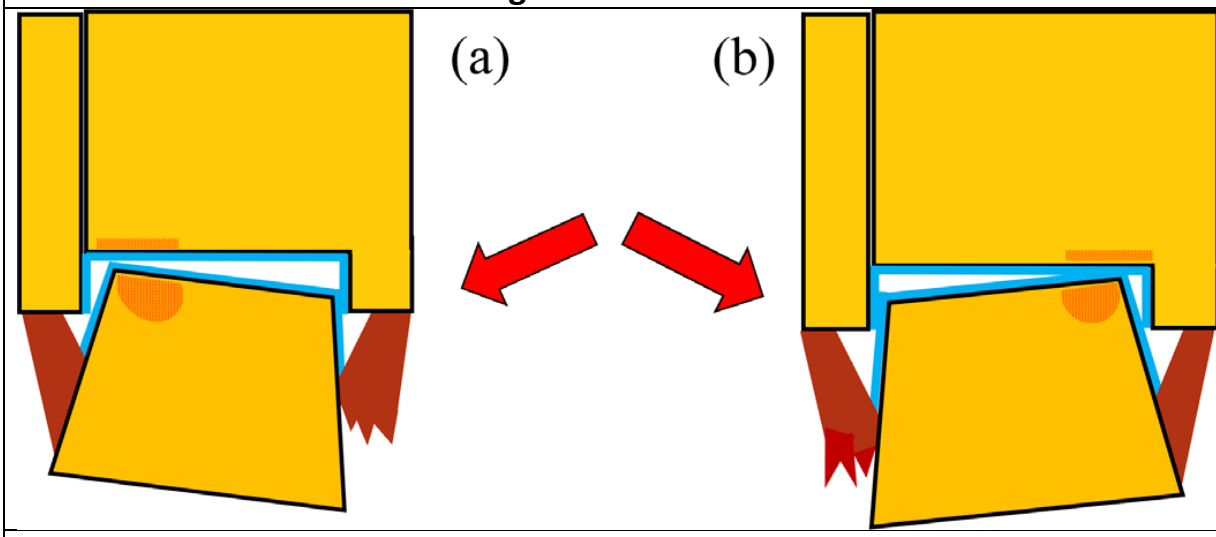
Talus Osteochondral Lesion

- **Degenerative Osteoarthritis.**
- **Osteochondral Fracture.**
- **Osteochondritis Dissecans (OCD)**
- **Primary Osteonecrosis (AVN)**

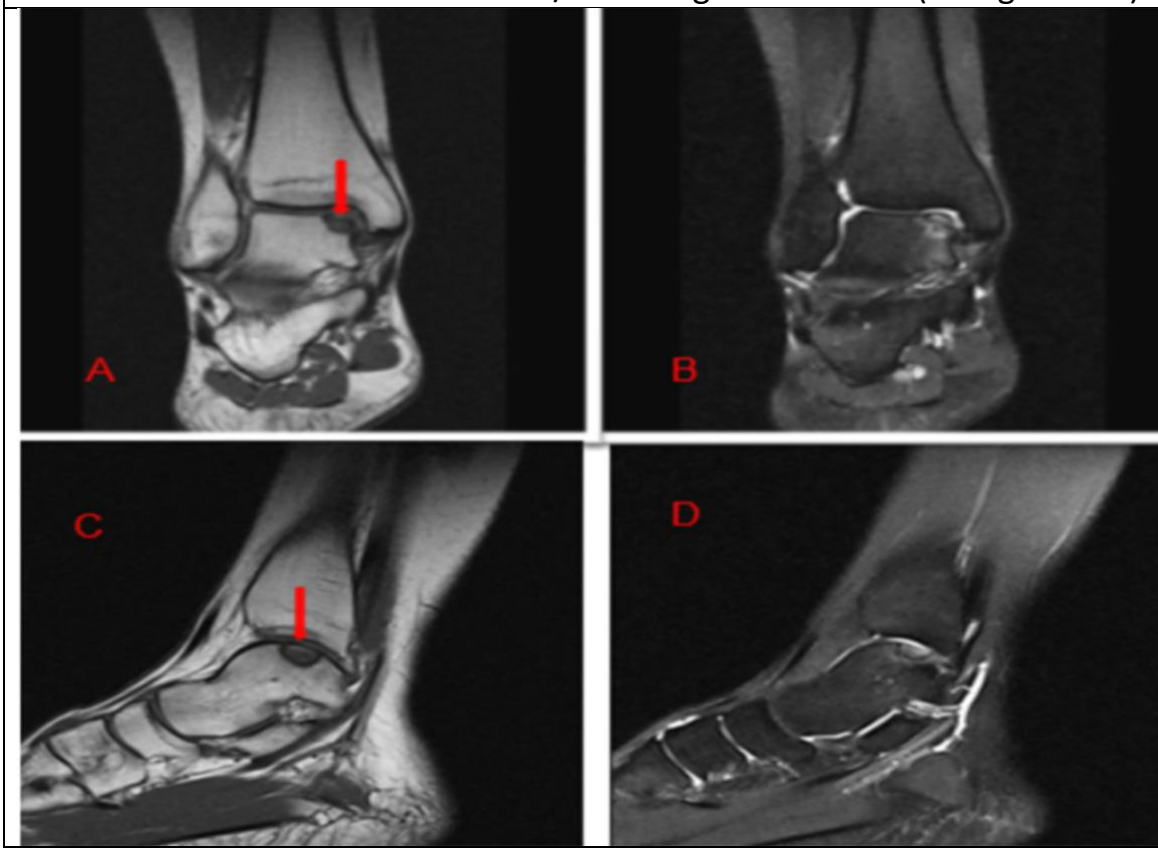
1a Bone marrow change (edema / cystic change) with no collapse of subchondral bone area, no osteochondral junction separation and intact cartilage
1b.Similar to grade 1a though with cartilage fracture
2a. Variable collapse of subchondral bone area with osteochondral separation though intact cartilage 2b. Similar to grade
2a though with cartilage fracture. This is an unstable lesion with level of instability related to extent of cartilage fracture
3a. Variable collapse of subchondral bone area with no osteochondral separation ± variable cartilage hypertrophy
3b. Similar to grade 3a though with cartilage fracture
4a. Separation within or at edge of bone component with intact overlying cartilage
4b. Similar to grade 4a though with cartilage fracture. This is an unstable lesion with level of instability related to extent of cartilage fracture
5. Complete detachment of osteochondral lesion. This is an unstable lesion


Grade 1a: Marrow changes with normal surface contour
Grade 1b: 1a & cartilage fracture
Grade 2a: Partial collapse of affected bone with osteochondral separation
Grade 2b: 2a & cartilage fracture
Grade 3a: Partial collapse of affected bone with cartilage hypertrophy
Grade 3b: 3a & cartilage fracture
Grade 4a: Bone separation, cartilage intact
Grade 4b: 4a & cartilage fracture
Grade 5: Complete bone and cartilage separation ± with bare area

❖ **Location of the OCL according to the mechanism of trauma**



a) Pronation injury => sprain of the medial collateral ligaments and lateral-sided OCL of the talar dome and/or kissing tibial lesion (orange zones).
b) Supination injury => sprain of the lateral collateral ligaments and medial-sided OCL of the talar dome and/or kissing tibial lesions (orange zones).



Ankle Fractures

A. Weber Ankle Fracture Classification

Classification of lateral malleolar fractures, relating to the level of the ankle joint, and determining treatment

Type A = Infra-syndesmotic:

1) Avulsion of the lateral malleolus below level of the ankle joint
2) Medial malleolus fracture (Uncommon)

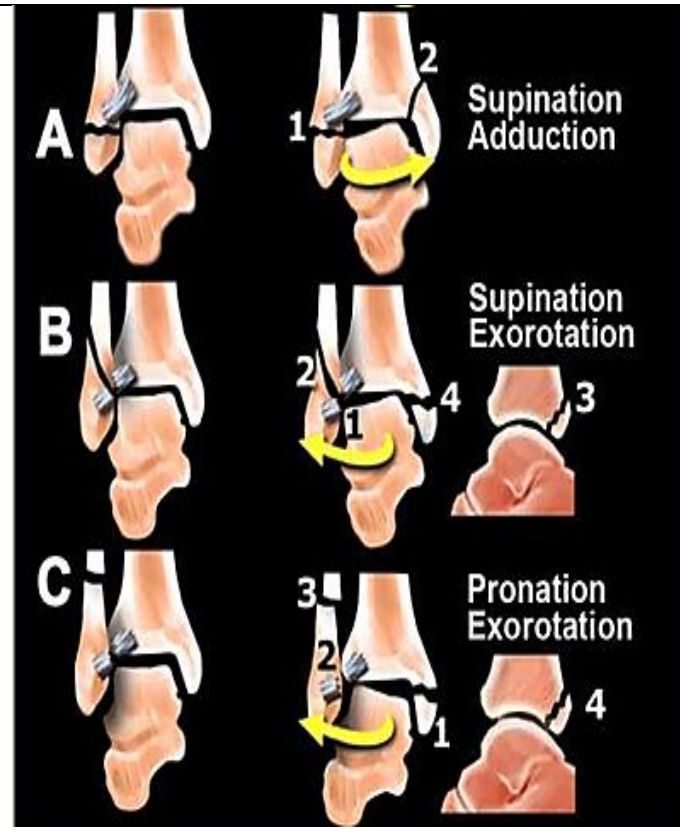
- Tibiofibular syndesmosis intact

Type B = Trans-syndesmotic:

1) Rupture of the anterior tibiofibular syndesmosis = Widening the space between distal tibia and fibula.
2) Oblique fracture of the fibula at the level of the ankle joint, extending superiorly and laterally up the fibula.
3) Rupture of the posterior tibiofibular syndesmosis or fracture of the posterior tibial malleolus.
4) Rupture of the deltoid ligament (widening the space between medial malleolus and talus) or fracture of the medial tibial malleolus.

Type C = Supra-syndesmotic:

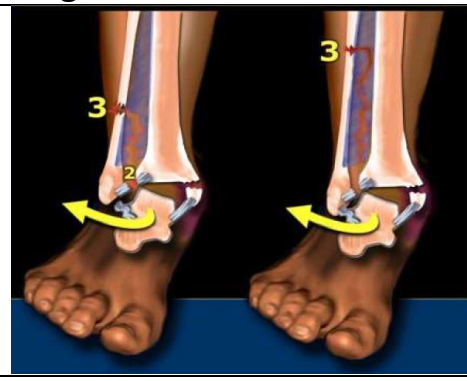
1) Rupture of the deltoid ligament or fracture of the medial tibial malleolus.
2) Rupture of the anterior tibiofibular syndesmosis
3) Fracture of the fibula above the level of the ankle joint
4) Rupture of the posterior tibiofibular syndesmosis or fracture of the posterior tibial malleolus.



Instability is seen in:

Weber A stage 2
Weber B stage 3 & 4
Weber C stage 3 & 4

Weber A	
Stage 1	**Stage 2**
Weber B	
Stage 1-2	
Stage 3-4	

Weber C	
Stage 1	**Stage 2-3**
	
Stage 3	

B. Pilon Fracture

- Pilon fractures are most often caused by high-energy impacts to the distal articular surface of the tibia.
- Fall from height
- Motor vehicle/motorcycle collisions
- Skiing

C. Talar Neck Fractures

❖ Hawkins-Canale Classification System for talar neck fractures:

Hawkins type I fracture
Nondisplaced fracture of the talar neck + NO dislocation.

Hawkins type II fracture
Displaced fracture through the talar neck +
Subluxation or dislocation of the subtalar joint.

Hawkins type III fracture
Displaced fracture through the talar neck +
Subluxation or dislocation of the subtalar and tibiotalar joints.

Hawkins type IV fracture
Displaced fracture through the talar neck with displacement of the talar head +
Subluxation or dislocation of the subtalar, tibiotalar and talonavicular joints

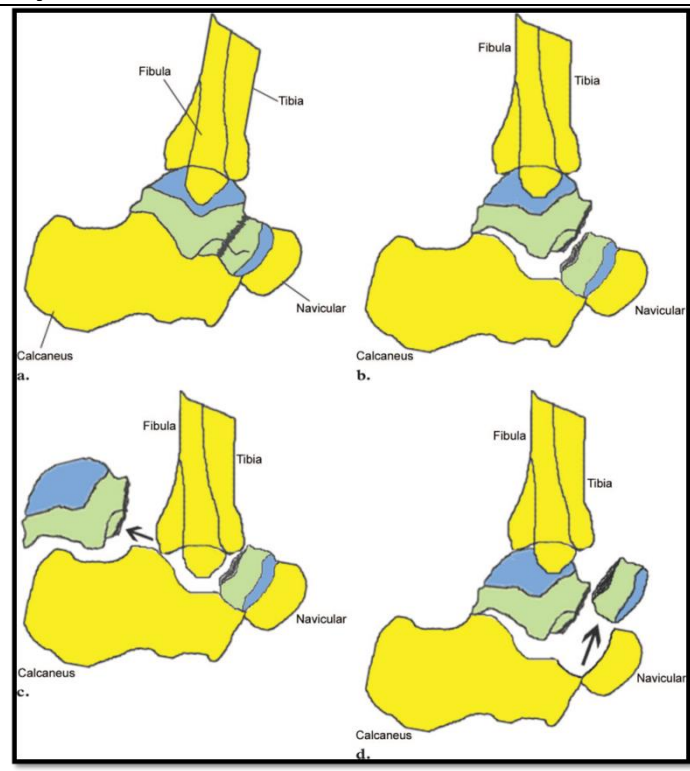


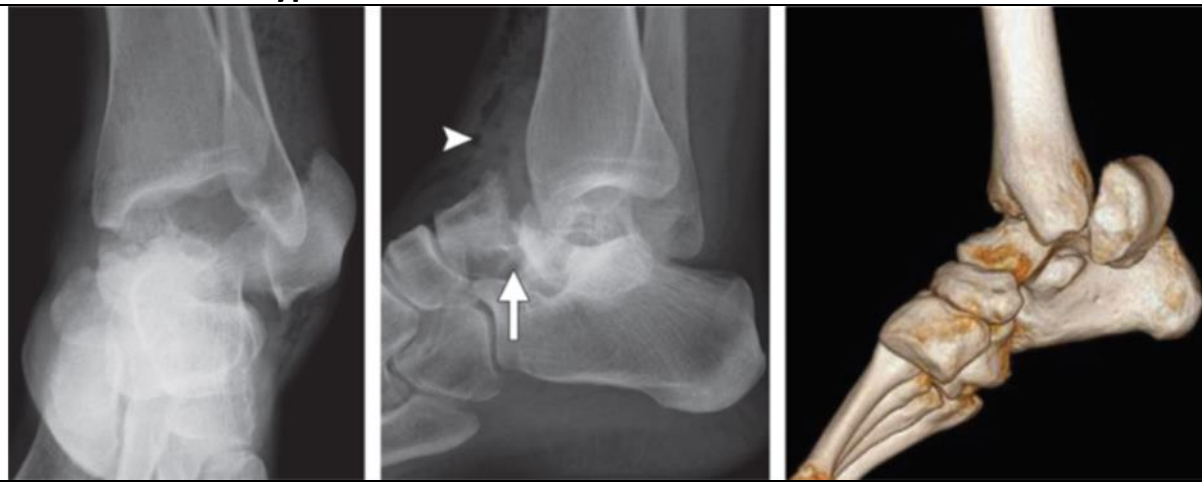
Table 1: Risk of Osteonecrosis in Hawkins-Canale–Type Talar Fractures

Fracture Type	Description	Risk of Osteonecrosis (%)
I	Nondisplaced talar neck fracture	0–15
II	Talar neck fracture and talocalcaneal dislocation	20–50
III	Talar neck fracture, talocalcaneal dislocation, and tibiotalar dislocation	100
IV	Talar neck fracture and disruption of all talar articulations	100

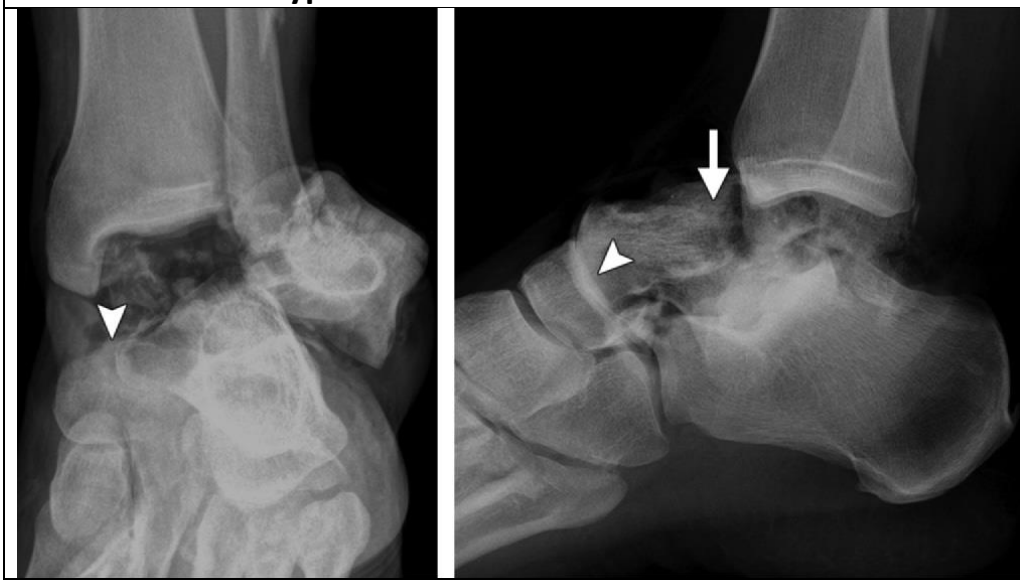
Hawkins type I fracture

Hawkins-Canale type II talar neck fracture

Hawkins-Canale type III talar neck fracture



Hawkins-Canale type IV talar neck fracture.



D. Talar Body Fractures

Table 2: Sneppen Classification of Talar Body Fractures

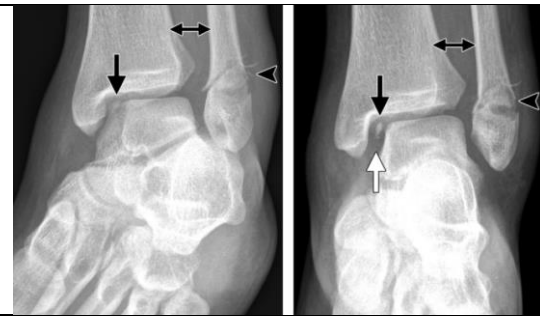
Type	Description
A	Compression or osteochondral dome fracture
B	Coronal shear fracture
C	Sagittal shear fracture
D	Posterior tubercle fracture
E	Lateral tubercle fracture
F	Crush comminuted fracture

Sagittal shear talar body fracture

Coronal shear talar body fracture

Lateral talar dome osteochondral fracture

Medial talar dome osteochondral fracture

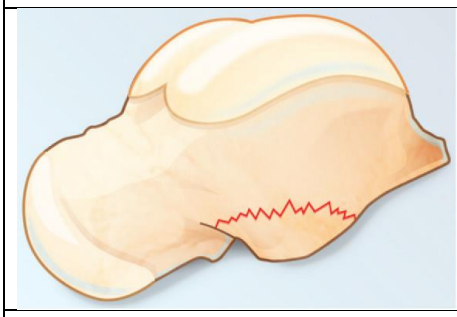


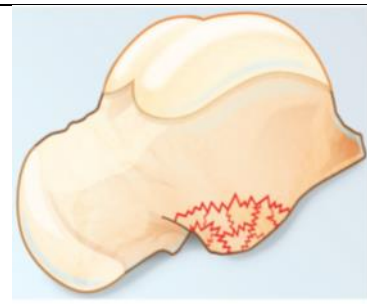
Posterior process fracture

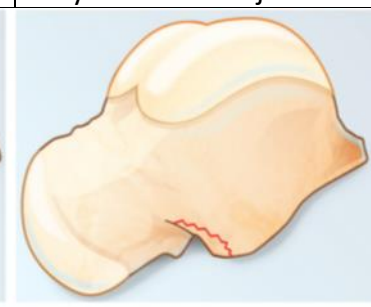
E. Talar Lateral Process Fractures

❖ Hawkins Classification

Type I (Simple)	type II (Comminuted)	Type III (Chip)
Fracture involves the talofibular articular surface and posterior talocalcaneal articular surface.	Fracture involves both articular surfaces and the entire lateral process.	Fracture involves the anterior-inferior portion of the posterior articular process and thus involves only the subtalar joint.





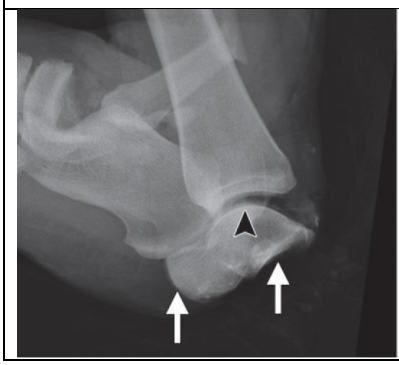


Hawkins type I lateral process fracture.

Hawkins type II lateral process fracture

F. Subtalar Dislocation

Subtalar dislocation is an uncommon type of injury that involves concomitant loss of normal anatomic relations between the talus, navicular, and calcaneus, while the tibiotalar and calcaneocuboid joints remain congruent



G. Pan-Talar Dislocation

Dislocation of the talus from all its articulations

H. Calcaneal Fractures

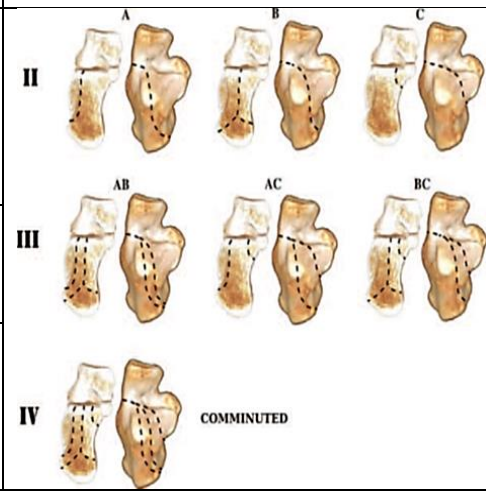
❖ Sanders Classification of Intraarticular Calcaneal Fractures

Type I fractures:
Displacement < 2 mm
Regardless of fracture lines

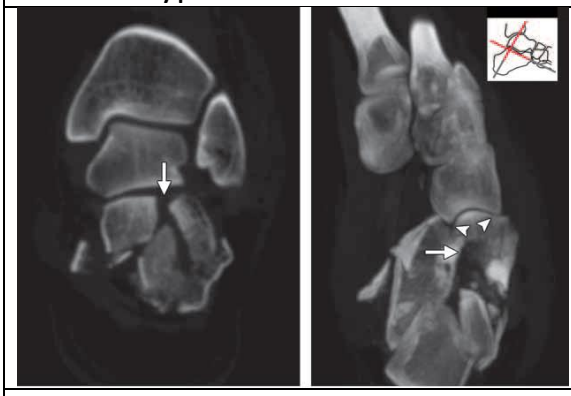
Type II fractures:
2 articular pieces from a single intraarticular fracture line and are divided into 3subtypes on the basis of whether the fracture line location is lateral (IIA), central (IIB), or medial (IIC).

Type III fractures:
3 articular pieces from 2 fracture lines and are subdivided into types IIIAB, IIIAC, and IIIBC

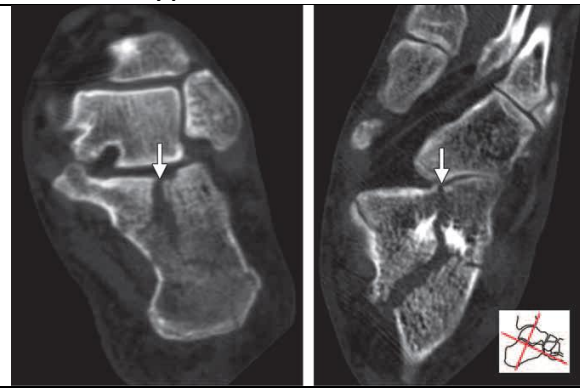
Type IV fractures:
> 3 intraarticular fracture lines are considered comminuted



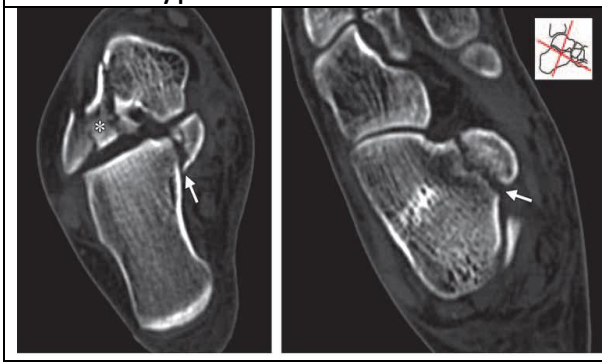
Sanders type IIA fracture



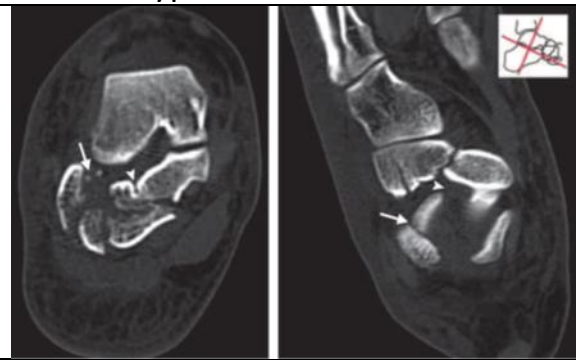
Sanders type IIB fracture

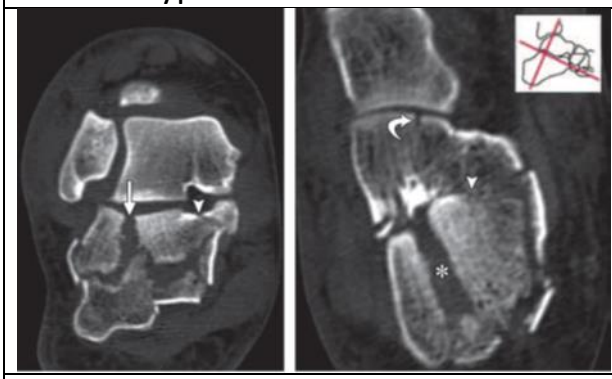
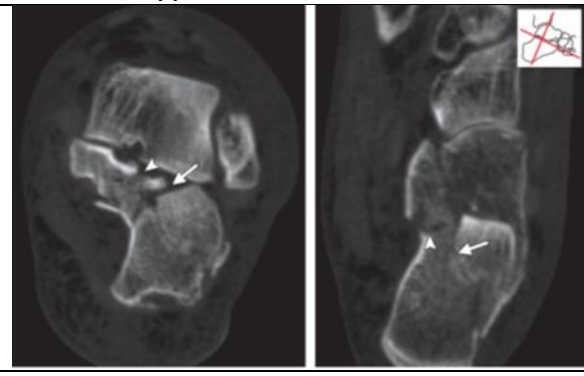
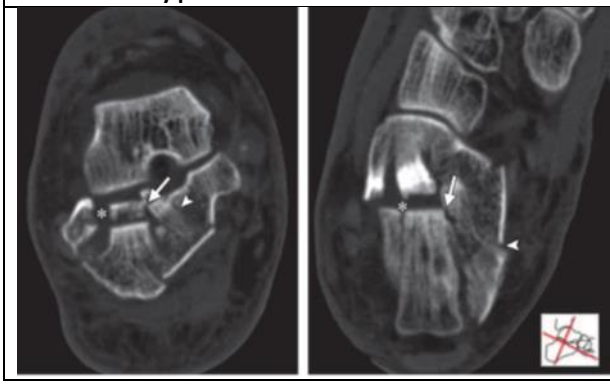


Sanders type IIC fracture



Sanders type IIIAB fracture



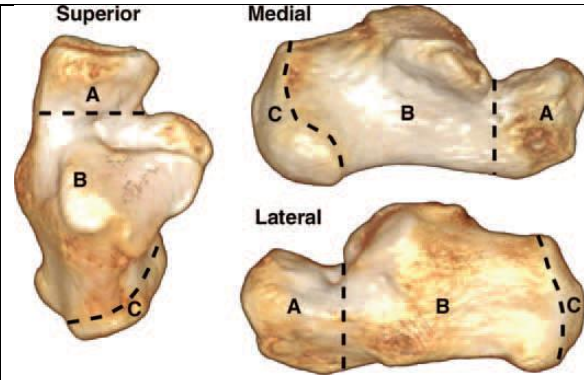
Sanders type IIIAC fracture	Sanders type IIIBC fracture
	
Sanders type IV fracture	
	

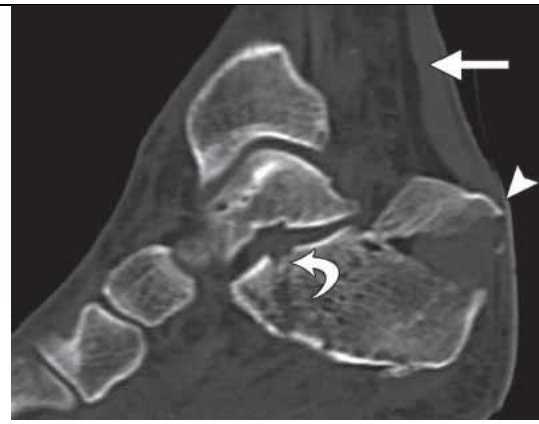
❖ Extra-articular Calcaneal Fractures

<u>Type A = Anterior calcaneus fractures</u>
involve the anterior process of the calcaneus

<u>Type B = Midcalcaneus or body Fractures</u>
Including the trochlear process, sustentaculum tali, and lateral process.

<u>Type C = Posterior calcaneus Fractures:</u>
including the posterior tuberosity and the medial tubercle.



Type A extraarticular calcaneal fracture	Type B extraarticular calcaneal fracture.
Type C extraarticular calcaneal fracture.	Achilles tendon avulsion fracture.
	

Foot

I- Fore Foot

- **Trauma:**
  - **Turf toe**
  - **Plantar Plate Disruption**
  - **Sesamoiditis**
  - **Stress fracture**
- **Osteochondral Lesions:**
  - **Osteochondritis Dissecans of 1st Metatarsal head**
  - **Freiberg infraction**
- **Arthritis**
  - **Septic Arthritis and Osteomyelitis**
  - **Osteoarthritis**
  - **Gout Arthritis**
- **Tendon disorders (eg, tendinosis, tenosynovitis, tendon rupture)**
- **Non-neoplastic soft-tissue masses**
  - **Ganglia**
  - **Bursitis**
  - **Foreign Body Granuloma**
  - **Morton neuroma**
- **Soft-tissue and bone neoplasms.**

A. Turf Toe

- Turf toe is a common injury in professional athletes, especially football players on artificial surfaces
- Acute hyperextension injury at the 1st metatarsophalangeal joint.

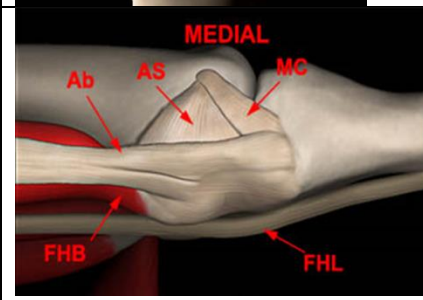
- MRI: increased T2 signal in the plantar soft tissue with partial or complete capsuloligamentous plantar plate injury.

Normal Plantar Plate:

- A fibrous structure that extends from the volar aspect of the metatarsal necks to the proximal phalanges of the toes
- Reinforces and blends with MTP joint capsule
- Embedded within it medial (M) and lateral (L) sesamoids.
- The sesamoid phalangeal ligaments (arrows)
- Intersesamoid ligament (asterisk)

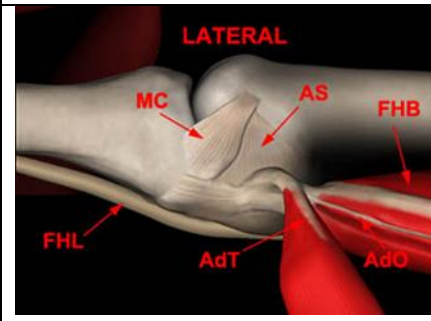
Medial view of the great toe metatarsophalangeal joint

- Plantar capsulo-ligamenotus-sesamoid complex:
- Main collateral ligament (MC)
- Accessory sesamoid ligaments (AS)
- Abductor hallucis (Ab) tendon inserts on the medial sesamoid and blends with the capsular structures on the medial side of the joint.
- The medial head of the flexor hallucis brevis (FHB) insert on to the sesamoids found along the plantar surface of the metatarsal

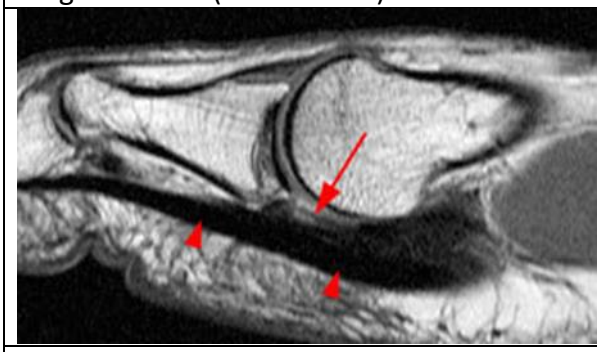
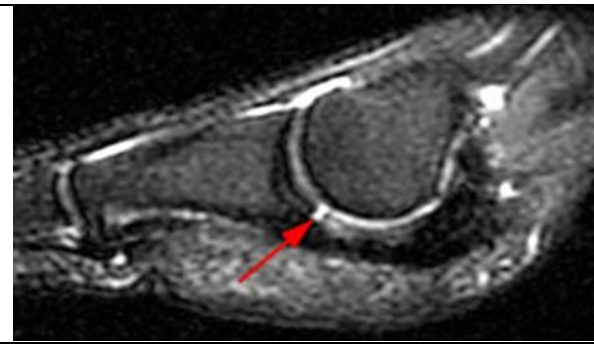


Lateral view of the great toe metatarsophalangeal joint:

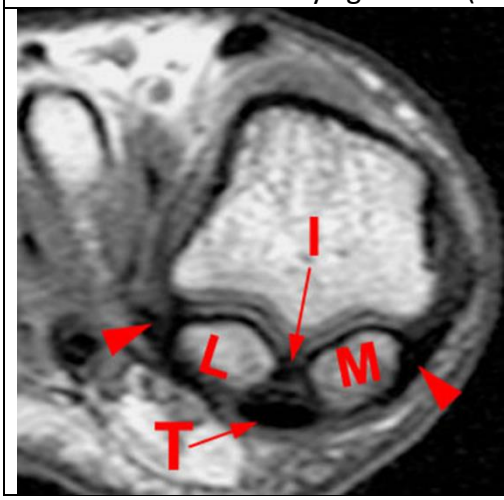
- Plantar capsulo-ligamenotus-sesamoid complex:
- Main collateral ligament (MC)
- Accessory sesamoid ligaments (AS)
- Adductor hallucis (oblique and transverse heads (AbO and AdT) tendon inserts on the lateral sesamoid and blends with the capsular structures on the lateral side of the joint.
- The lateral head of the flexor hallucis brevis (FHB) insert on to the sesamoids found along the plantar surface of the metatarsal

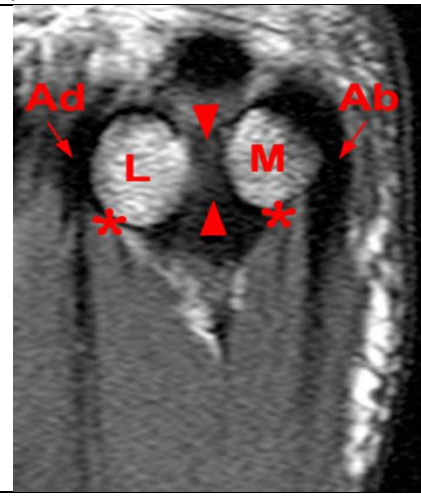


❖ Normal Plantar Plate

Mid-Sgaittal T1	Mid-Sagittal STIR
Plantar Plate = Thin low signal intensity (arrow). The midline location is confirmed by the visualization of the underlying flexor hallucis longus tendon (arrowheads)	Normal distal recess (arrow) found at the phalangeal insertion of the plantar plate = smooth, fairly small, and well defined appearance.
	

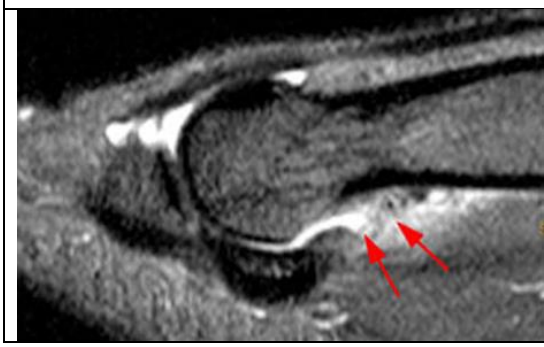
Medial (M) and lateral (L) sesamoids.
The flexor hallucis longus tendon (T) lies plantar to the intersesamoidal ligament (I).
Normal medial and lateral attachments of the abductor and adductor hallucis tendons and the sesamoid accessory ligaments (arrowheads).

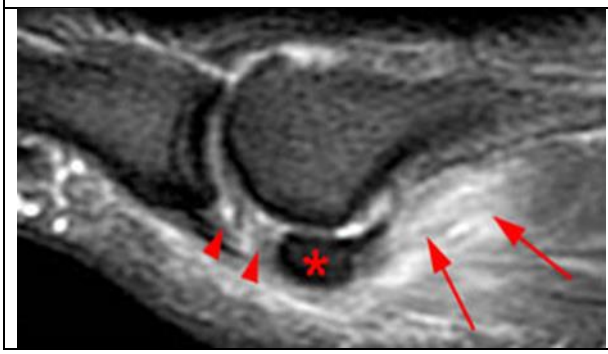
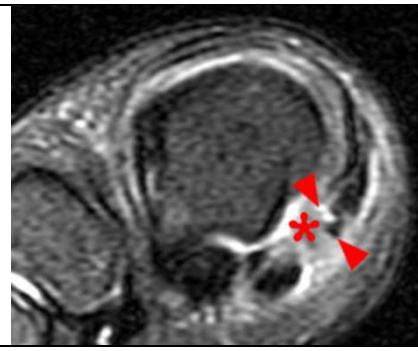




❖ Grading

- Grade 1 - stretch or minor tearing of the 1st MTP capsuloligamentous structures
- Grade 2 - partial tearing of the capsuloligamentous structures with intact articular surface
- Grade 3 - complete disruption of the capsuloligamentous structures with impaction deformity of the MTP, articular cartilage damage, trabecular edema, sesamoidal fracture, or diastasis of sesamoidal fragments

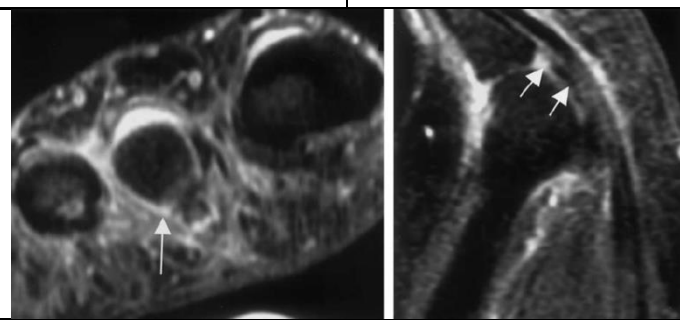
Proximal Plantar Plate Injury	Distal Plantar Plate Injury
Edema and irregularity (arrows) at the posterior capsular attachment of the medial sesamoid and distal metatarsal.	A fluid filled gap (arrow) at the typical distal insertion site of the plantar plate. The gap is too large and irregular to represent a normal recess Intact underlying flexor hallucis longus tendon (arrowhead).
	

Plantar Plate Injury Medial Sesamoid Phalangeal Ligament Injury	
Edema and discontinuity (arrowheads) along the plantar plate in the region of the medial sesamoid phalangeal ligament. The medial sesamoid (asterisk) is retracted proximally Edema compatible with a muscle strain (arrows) within the medial head of the flexor hallucis brevis. Associated tears of the medial capsular and abductor hallucis attachments (arrowheads) of the medial sesamoid.	
	

B. Plantar Plate Disruption

- 2nd – 5th MTP joints
- occurs more frequently in women.
- The increased weight-bearing load and hyperextension forces placed on the MTP joint by high-heeled, pointed shoes.

Edema and disruption of the plantar plate of 2nd MTP joint	Tenosnovitis of the flexor tendon

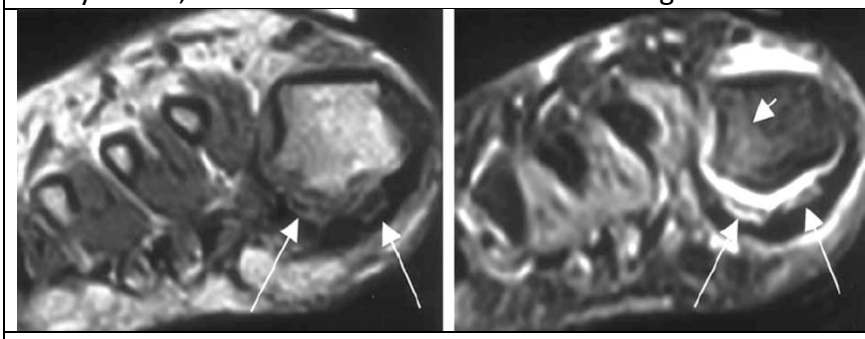


C. Sesamoiditis

- Sesamoiditis is a painful inflammatory condition produced by repetitive injury to the plantar aspect of the forefoot.

MRI findings in the marrow of the sesamoid bones

- T1: decreased or normal signal intensity
- STIR: increased signal intensity
- Reactive soft-tissue abnormalities including soft tissue edema, joint effusion, tendinitis, synovitis, and bursitis are characteristic findings



Bi-partite medial hallucal sesamoid with bone marrow edema on either side of syndesmosis

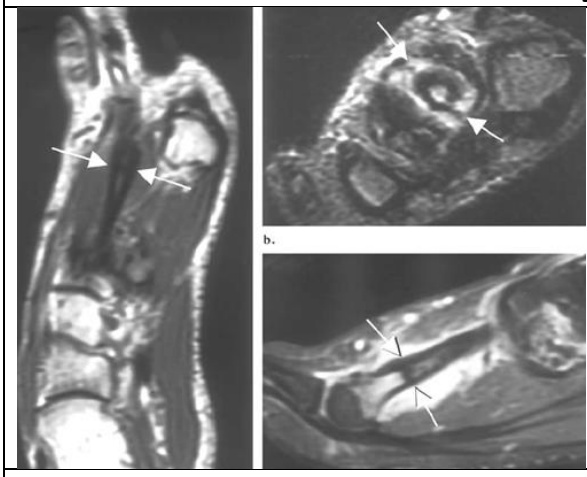
D. Stress Injury / Fracture

- Stress fractures in the metatarsal bones are common in runners, ballet dancers, gymnasts, and military recruits.
- The middle or distal portions of the 2nd, 3rd and 4th metatarsal shafts are most often involved.

MRI Grading

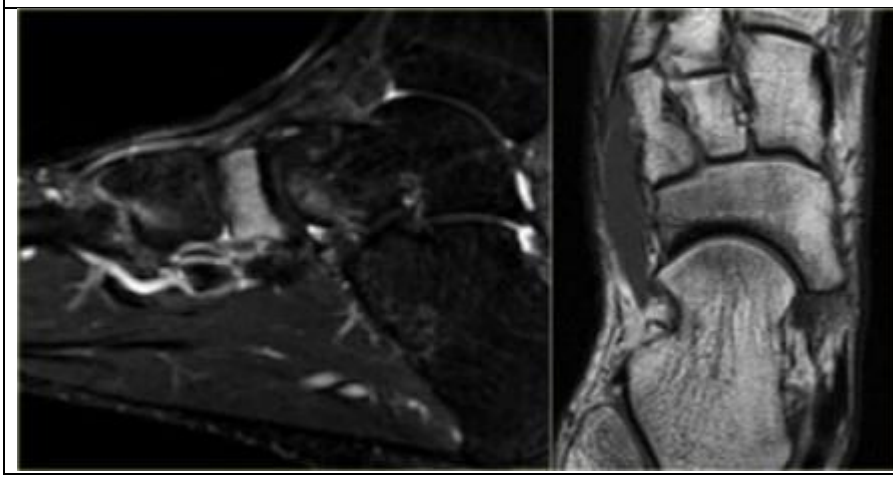
- Grade 1: subtle periosseous edema that may be seen only on STIR images.
- Grade 2: subcortical bone marrow edema and periosseous soft-tissue edema on T2- FS images, without corresponding hypointense signal on T1-images.
- Grade 3: extensive periosseous edema and bone marrow edema, seen on both T2- and T1-weighted images.
- Grade 4: stress fracture with a discrete low signal fracture line visible at MR imaging

❖ Metatarsal bones Stress Injury / Fracture



❖ Tarsal bones Stress Injury / Fracture

The navicular bone is the most common site for stress fractures of the tarsus.



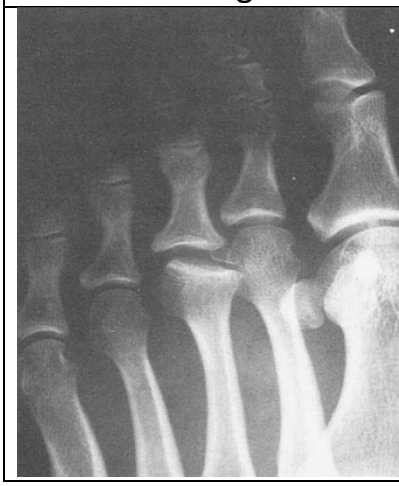
E. Osteochondral Lesions of 1st metatarsal head

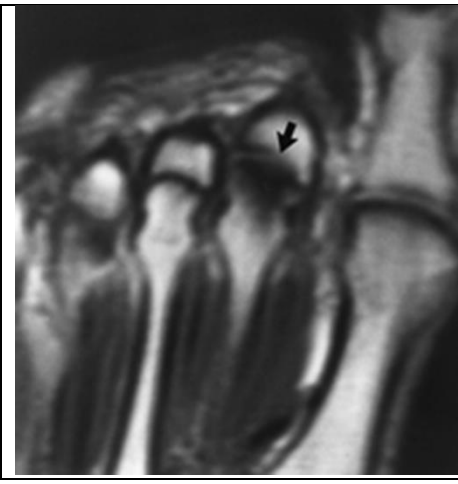
- Osteochondritis Dissecans commonly affects the 1st metatarsal head within the forefoot
- The familiar OD staging system can be applied to the OD of the 1st MTH.
- Osteochondral lesion of 1st metatarsal head in subarticular distribution.
- Low signal line demarcating bone fragment.
- Surrounding bone marrow oedema

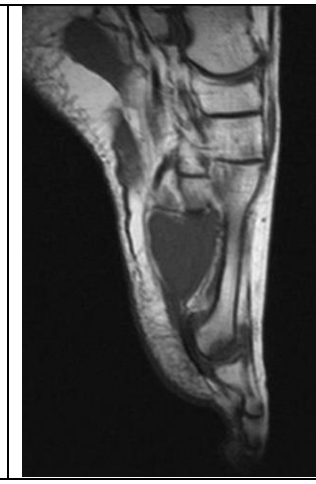
F. Freibergs Disease

- Osteochondrosis of the metatarsal heads
- Adolescent women (high heeled shoes are a risk factor)
- Typically affects the 2nd and 3rd metatarsal heads

Early: Bone marrow edema = Low T1 + High T2/STIR
Then: Bone sclerosis = Low signal on T1 + T2/STIR
Late: Flattening of the metatarsal heads







G. Osteomyelitis + Septic Arthritis

- Osteomyelitis and septic arthritis of the foot most often results from transcutaneous spread of infection
- Most commonly occurs in diabetic patients.
- Pressure points especially under the first and fifth metatarsal heads => Cutaneous ulcers => Infected ulcers => Spread of infection to the underlying metatarsal heads + MTP joints + Soft tissue => Osteomyelitis + Septic arthritis + Cellulitis.

Osteomyelitis = Infected Bone Marrow

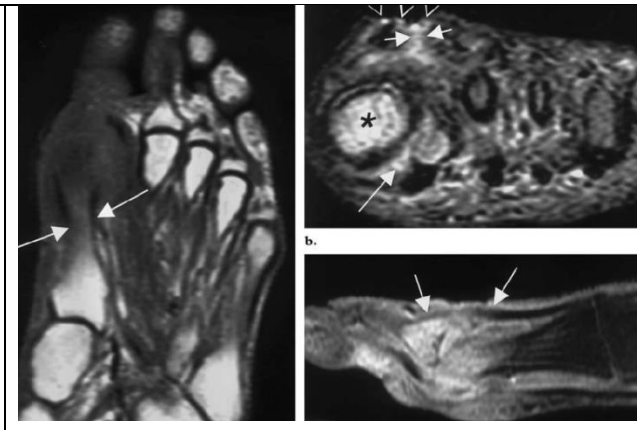
- T1:low signal intensity
- STIR increased signal intensity
- T1+C: contrast enhancement

Septic Arthritis:

- Joint effusion
- Synovial thickening and enhancement

Secondary signs (DD: help distinguish between osteomyelitis and acute neuropathic disease)

Cutaneous ulcer, cellulitis, phlegmon, soft-tissue abscess, sinus tract, and cortical interruption.



H. 1st MTP joint Osteoarthritis

- Produced by repetitive loading injury.
- Osteoarthritis of the hallucal sesamoid articulations is also common.
- A hallux valgus deformity may precipitate degenerative changes

Imaging Findings:

Medial joint space narrowing
Subchondral marrow edema (Low T1 and high T2)
Subchondral sclerosis (low T1 and T2)
Subchondral pseudo-cyst formation
Marginal osteophyte (long arrow)
ossicles at the lateral joint margin (short arrows)

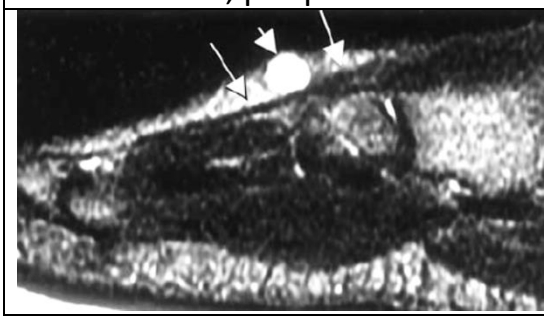
I. Gout Arthritis (See Chapter of Arthritis)

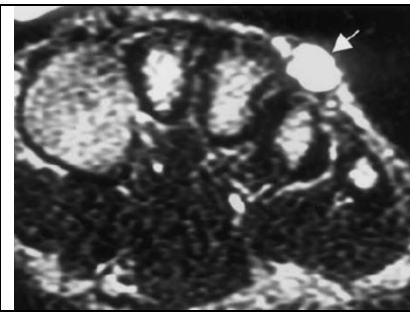
J. Ganglion Cyst

- Ganglia are the most common soft-tissue masses of the foot and ankle.
- In the forefoot, a ganglion is typically located dorsal to the MTP joints and tendons.

Imaging Findings:

- A well-defined lesions
- T1: low to intermediate signal intensity depending on its protein content.
- STIR: Homogeneous high signal intensity
- T1+C: Thin, peripheral rim enhancement.



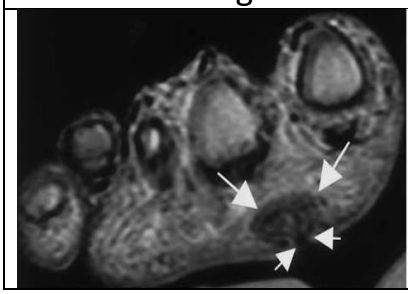


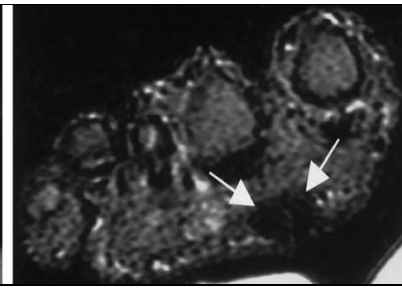
K. Foreign Body Granulomas

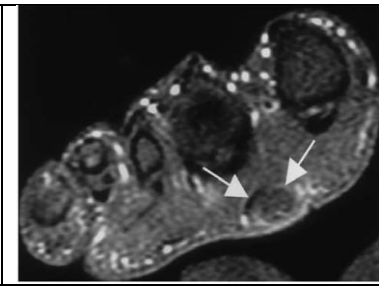
- Foreign body granulomas form in response to foreign objects such as thorns or pieces of wood, glass, or plastic that have penetrated the soft tissues of the foot

Imaging Findings:

- Ill defined heterogeneous lesion.
- T1: Low signal
- T2: High signal
- Foreign body: Central areas of low signal in all pulse sequences.
- Surrounding inflammation







L. Bursitis

Locations:

- **Bunion** = Medial aspect of the 1st metatarsal head
  - Hallux valgus of the 1st metatarsophalangeal joint
  - Medial deviation or adduction of the first metatarsal
  - Increased first-second metatarsal angle.
- **Bunionette** = Lateral aspect of the 5th metatarsal head
  - Increased angulation between the 4th and 5th metatarsals
  - Enlargement of the head of 5th metatarsal (dumbbell-shaped)
  - Lateral bowing of the 5th metatarsal shaft
  - Medial deviation of phalanges of 5th toe
- **Sub-metatarsal bursitis** = Plantar aspect of the metatarsal heads
- **Inter-metatarsal bursitis** = In-between metatarsal heads

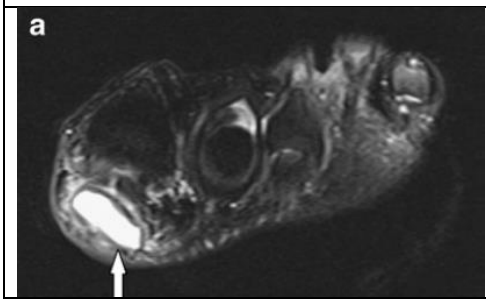
Imaging Findings:

- A well-defined lesions
- T1: low to intermediate signal intensity depending on its protein content.
- STIR: Homogeneous high signal intensity
- T1+C: Thin, peripheral rim enhancement

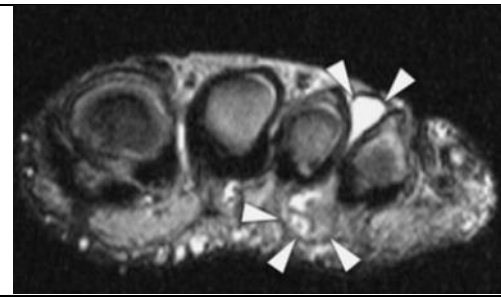
Bunion

Bunionette

Sub-metatarsal bursitis



Intermetatarsal bursitis



M. Morton Neuromas

- Misnomer; non-neoplastic; does not represent a true neuroma
- Perineural fibrosis around a plantar digital nerve of the foot.
- The condition is thought to be due to chronic entrapment of the nerve by the intermetatarsal ligament

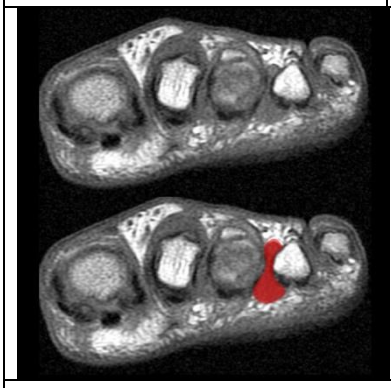
Location

- 3rd web-space (between 3rd and 4th metatarsal heads) is most commonly affected site.
- 2nd web-space is less often involved
- The remaining web-spaces are rarely involved

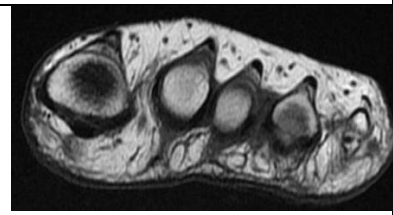
MRI:

- T1: typically low-to-iso signal
- T2: typically low signal but can sometimes be intermediate in signal
- T1 C+ (Gd): tends to show intense enhancement

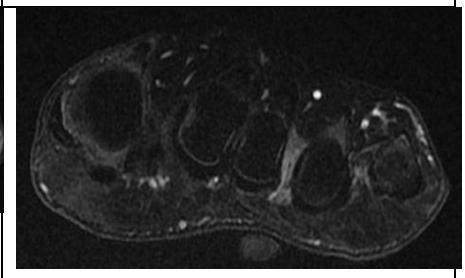
Coronal T1



Coronal T2

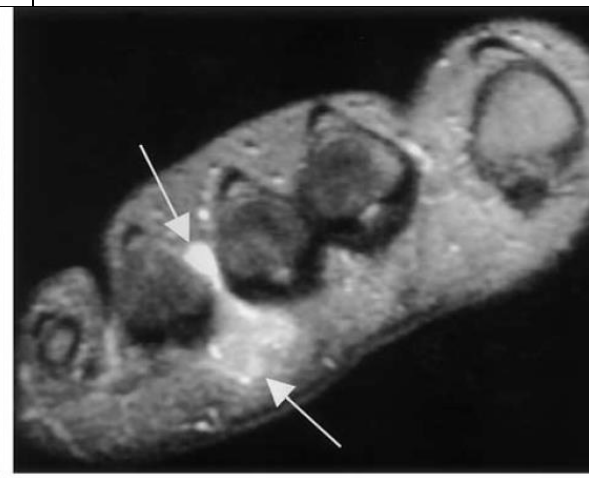


Coronal T1 FS +C



Coronal T1 Pre-Contrast

Coronal T1 Post-contrast



II- Hind Foot / Heel

- **Plantar fascial lesions**
  - Plantar fasciitis
  - Plantar rupture
  - Plantar fibromatosis
  - Plantar xanthoma
- **Bursal lesions**
  - Retro-calcaneal bursitis
  - Retro-achilleal bursitis
- **Calcaneal osseous lesions:**
  - Fractures, bone bruises
  - Osteomyelitis (See chapter of Diabetic foot)
  - Tumors (UBC, ABC, Lipoma, GCT, Ewing Sarcoma)
- **Achilles Tendon:**
  - Insertional tendinitis (Haglund Syndrome)
  - Tendon Rupture
- **FHL:**
  - Tenosynovitis
- Tarsal tunnel syndrome
- Heel plantar fat pad abnormalities

A- Plantar Fasciitis

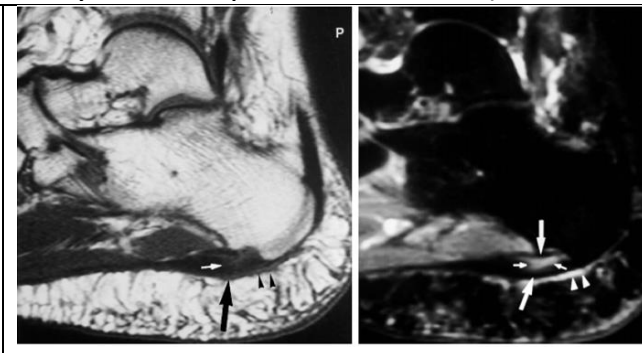
Normal plantar fascia:

- Thin band (<4mm)
- Low signal on all MR pulse sequences.

- Plantar fasciitis is the most common cause of plantar heel pain
- This condition can arise either from:
    - Stress of repetitive trauma (athletic activities, excessive job-related standing and walking, changes in walking surfaces, or changes in shoewear)
    - Enthesopathy in association with seronegative spondyloarthropathies (ankylosing spondylitis, Reiter syndrome, psoriatic arthritis)

T2/STIR:

- Thickening of plantar fascia > 4 mm at its insertion on the calcaneus.
- High signal within the plantar fascia
- High signal within the plantar aspect of the calcaneus.
- High signal within adjacent subcutaneous fat representing edema.

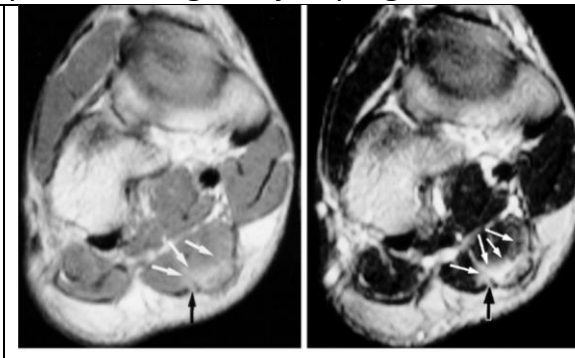


B- Plantar Fascia Rupture

- Rupture of the plantar fascia is typically a sports related injury, particularly in athletes engaged in sports that require running and jumping.

Imaging Findings:

- Partial or complete interruption of the normally low-signal- fascia
- Large areas of increased signal on T2/STIR representing edema and haemorrhage.
- Tears of the plantar fascia commonly involve the underlying FDB muscle.



C- Plantar Fibromatosis

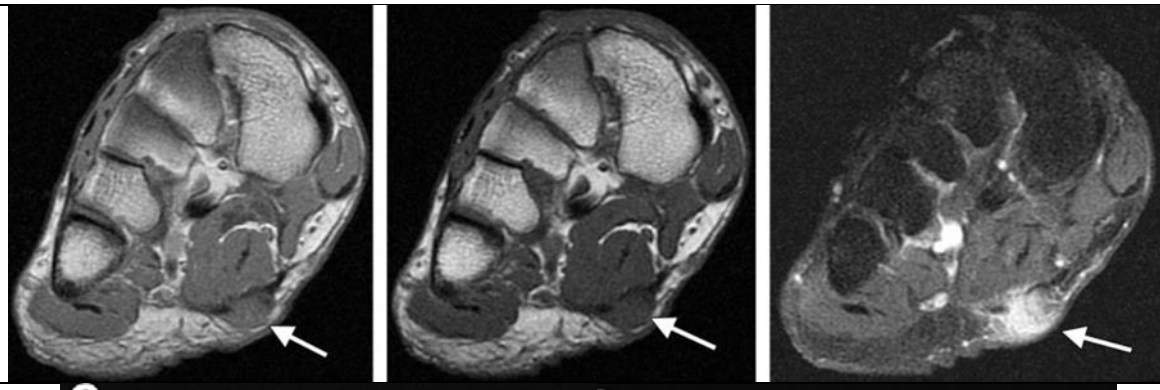
- Develop most commonly in the medial aspect of the plantar aponeurosis.
- Age: 30 and 50 years.
- Bilateral in 20%– 50% of cases.
- Concomitant palmar fibromatosis in 10%–65% of patients

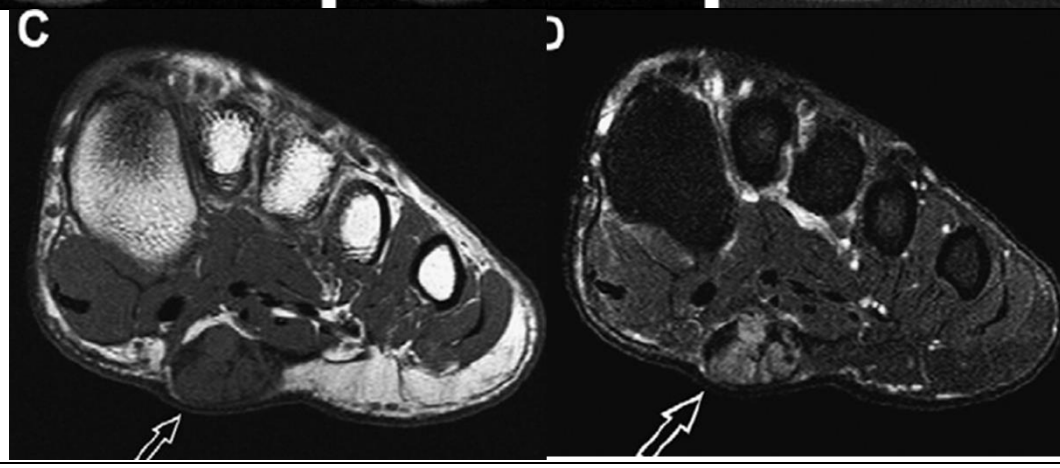
Clinical Presentation:

- They usually manifest as one or multiple firm, fixed, subcutaneous nodules, which can extend to involve the skin or invade the deep structures of the foot

Imaging Findings:

- Ill defined, infiltrative mass occurring in the deep aponeurosis adjacent to the plantar muscles in the medial aspect of the foot
- T1: Low signal
- T2:
    - Low signal (due to hypocellularity & predominant dense collagen)
    - Intermediate - High signal (more cellular & relatively less collagen and thus more likely to locally recur)
- +C: variable enhancement.





D-Plantar Fascia Xanthoma

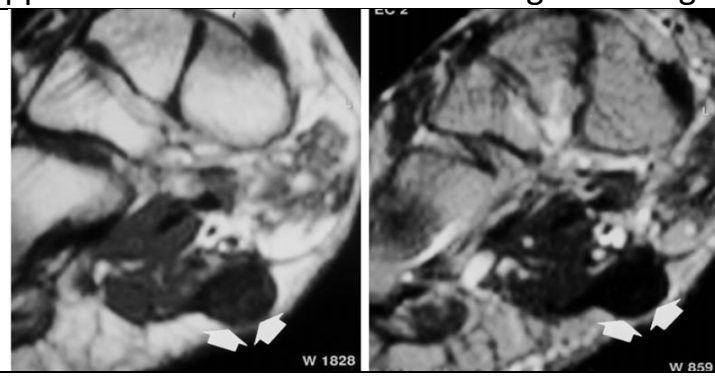
- Xanthomas are a prominent feature of several types of primary hyperlipidemias
- Tendon xanthomas are usually bilateral and symmetric.

Location:

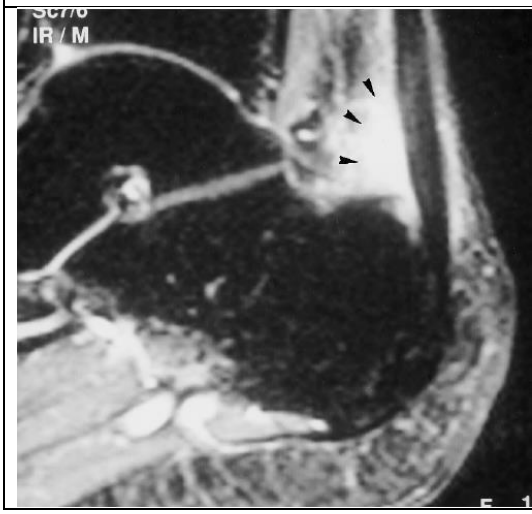
- Finger extensors in the dorsum of the hands
- Achilles tendons near their insertion on the calcanei
- Plantar fascia is occasionally infiltrated
- Extensor tendons of the toes are more rarely involved

Imaging Findings:

- Fusiform tendinous or aponeurotic enlargement
- Heterogeneous signal intensity
- Small foci of increased signal intensity corresponding to the xanthomatous deposits, along with trabeculated low signal- intensity areas representing the remaining tendinous fascicles, produce a characteristic speckled or reticulated appearance on both T1- and T2-weighted images



E- Retro-calcaneal bursitis



F- Retro-achilleal Bursitis

III- Mid Foot

- **Plantar Tendons:** (Chapter of Ankle)
  - Peroneus Longus
  - FHL & FDL
  - Distal Posterior Tibial Tendon
- **Tarsal bones:**
  - Tarsal Coalition
  - Köhler's Disease
  - Sever' Disease
- **Ossicles**
  - Os Naviculare
  - Os Peroneum
  - Os Intermetatarseum
  - Os Trigonium
- **Metatarsal bones:**
  - Stress Injury / fracture
  - Dancer Fracture
- **Tarso-metatarsal Joint:**
  - Lisfranc Joint Complex
  - Neuropathic Arthropathy (Chapter of Diabetic Foot)

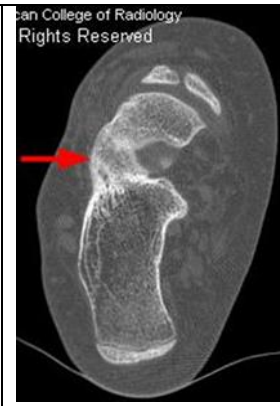
A- Tarsal Coalition

- Tarsal coalition may be osseous, fibrous, or cartilaginous.
- Coalition can occur congenitally, or be acquired postinfection, surgery, inflammation, or trauma.

Location:

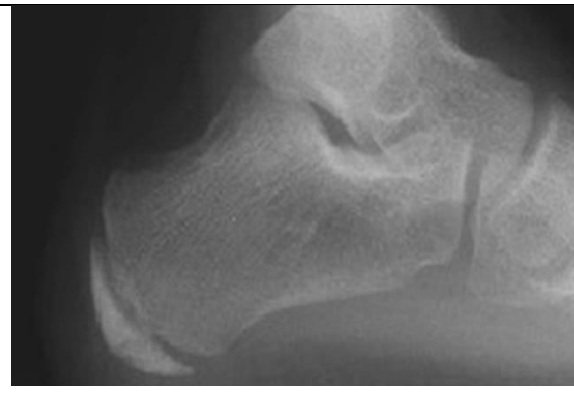
- Talocalcaneal most commonly
- Calcaneonavicular.
- Talonavicular is less common.

❖ **Talocalcaneal coalition**



❖ **Calcaneonavicular Coalition = Anteater Sign**

B- Köhler's Disease	C- Sever' Disease
Avascular necrosis of navicular bone	Calcaneal apophysis
Patchy sclerosis + Collapse + Fragmentation.	



D- Lisfranc Joint Complex

- Tarso-metatarsal articulation of the foot.
- is articulation of the tarsus with the metatarsal bases.
- 1st – 3rd metatarsals articulate respectively with the three cuneiforms.
- 4th and 5th metatarsals articulate with the cuboid

AP Foot

- ✓ Continuity of the lateral margins of M1 and C1.
- ✓ Continuity of the medial margins of M2 and C2.
- ✓ Continuity of the medial and lateral margins of M3 and C3.
- ✓ Continuity of the medial margins of M4 and cuboid bone.
- ✓ C1-M2 distance < 2mm
- ✓ M1-M2 distance <2mm.

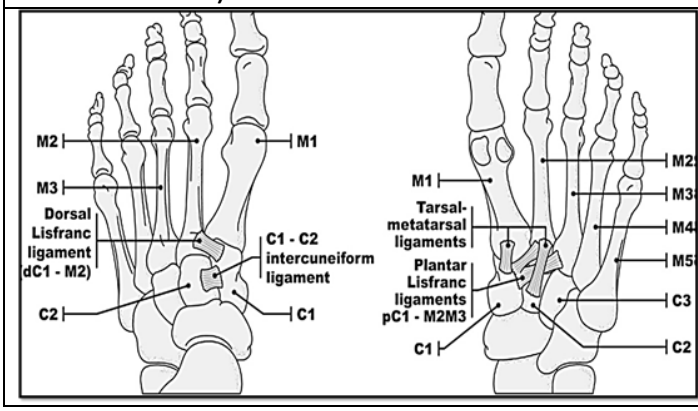
Lateral Foot:

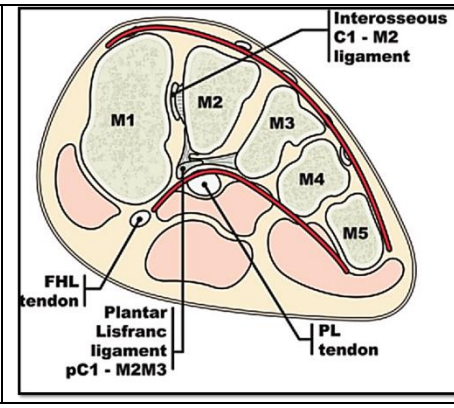
- ✓ Continuity of the dorsal surface of M1 base and C1 (dashed white line).
- ✓ The plantar surface of the M1 base (black line) is superior to the plantar surface of the M5 base (solid white line).

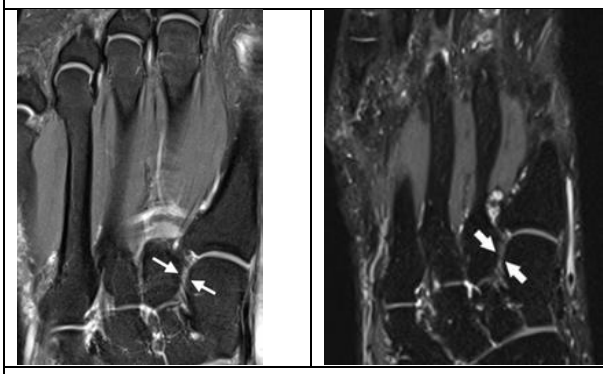
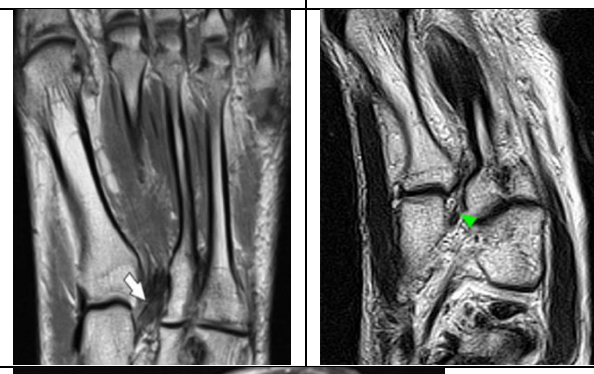
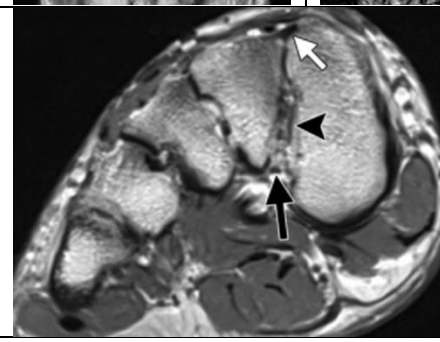
Lisfranc Ligament Complex:

3 distinct obliquely oriented ligaments:

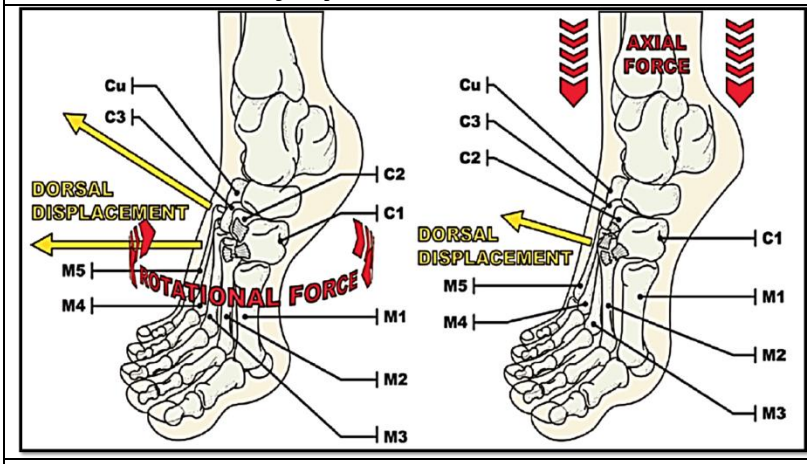
i. Lisfranc ligament proper: interosseous C1-M2 ligament
ii. Dorsal Lisfranc ligament: connects the dorsum of C1 and M2 (dC1-M2)
iii. Plantar Lisfranc ligament: from the plantar surface of C1 and sends separate bundles to the plantar surface of the M2 and M3 bases (pC1-M2M3)





Interosseous Lisfranc Ligament	Plantar Lisfranc ligament (pC1-M2M3)	
	M2 bundle	M3 bundle
		
Lisfranc ligament complex: Dorsal ligament (white arrow) Interosseous ligament (arrowhead) Plantar ligament (black arrow).		

Mechanism of Injury:



2 type of Injuries:

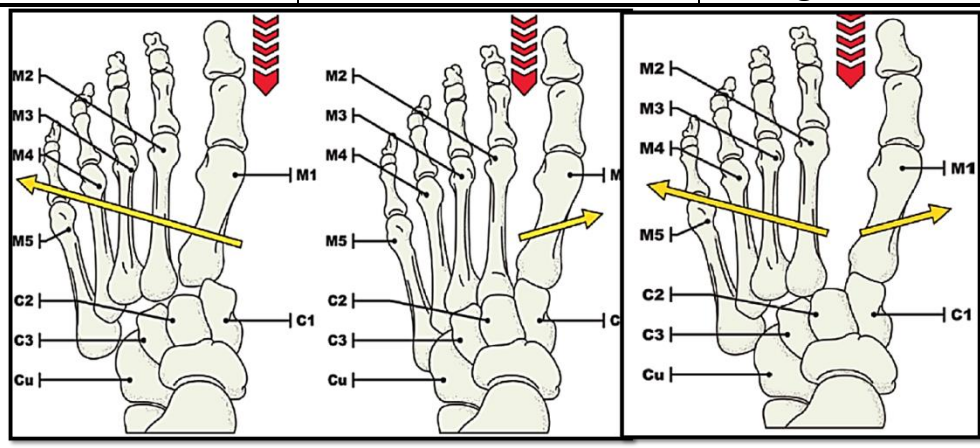
- **High-impact injuries = Lisfranc fracture-displacements:** usually due to greater energy forces such as motor vehicle collisions.
- **Low-impact injuries = Lisfranc injury = midfoot sprains:** are commonly incurred during athletic activities.

❖ High Grade Lisfranc Fracture-Displacement

Table 1: Quenü and Küss Classification of High-Grade Lisfranc Fracture-Displacements

Injury Type	Incongruity	Direction of Displacement
Homolateral	Complete	All five metatarsal bases are displaced in the same direction
Isolated	Partial	Displacement of one or two of the metatarsal bases
Divergent	Complete	M1 is displaced medially and M2–M5 are displaced laterally

Homolateral	Isolated	Divergent



Divergent Lisfranc Fracture-Dislocation

Medial dislocation of M1
Lateral dislocation of M2–M5
Cuboid fracture

Dorsal subluxation of M1 relative to C1 (arrow).

Homolateral Lisfranc Fracture-Dislocation

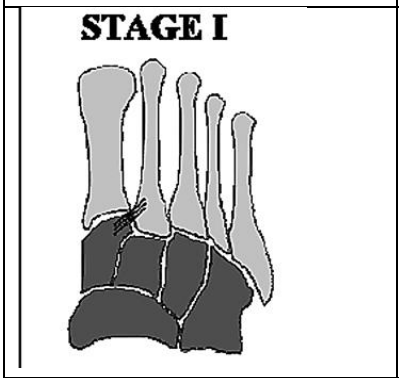
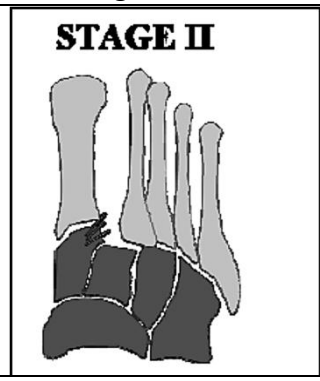
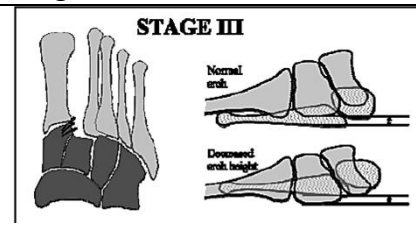
Lateral dislocation of M1–M5
Fracture at the base of M2

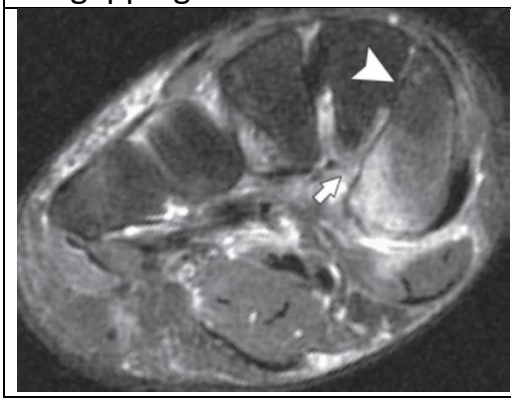
Dorsal subluxation of M1 relative to C1.

❖ Low Grade Lisfranc Injury:

Table 3: Nunley-Vertullo Classification of Low-Grade Midfoot Sprains

Stage	Clinical Findings	Findings at Weight-bearing Radiography and Bone Scintigraphy
I	Low-grade Lisfranc ligament complex sprain	Normal Increased radiotracer uptake
II	Lisfranc ligament insufficiency or disruption; intact plantar ligament	Anteroposterior: 2–5-mm M1-M2 diastasis Lateral: no loss of arch height
III	Interosseous and plantar Lisfranc ligaments disrupted	Anteroposterior: >5-mm M1-M2 diastasis Lateral: decreased distance between the plantar surfaces of C1 and M5 (loss of arch height)

Stage I	**Stage II**	**Stage III**
Lisfranc ligament sprain No diastasis	Ruptured Lisfranc ligament Diastasis without loss of arch height	Ruptured Lisfranc ligament Diastasis with loss of arch height
		

Stage I Lisfranc sprain	
Tear of the plantar Lisfranc ligament (arrow) with intact dorsal and interosseous Lisfranc ligaments (arrowhead). Multiple midfoot contusions (asterisks) No gapping	
	

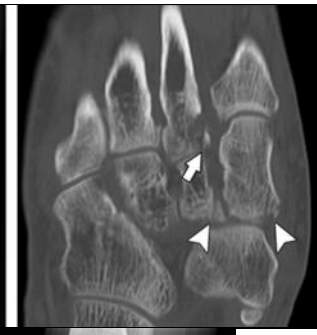
Stage II

Weight-bearing AP radiograph

Distance between C1 and C2, M1 and M1 and between C1 and M2 > 2mm

Off-step sign = discontinuation of line drawn along the medial aspect of C2 and M2.

Fleck sign = bone fragment at the region of Lisfranc ligament



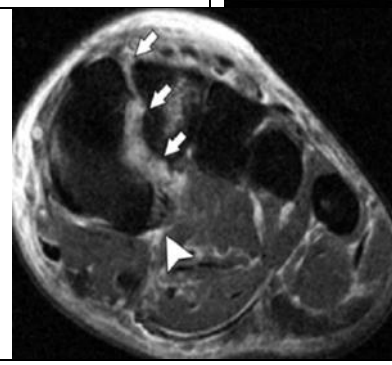
Weight-bearing lateral radiograph:

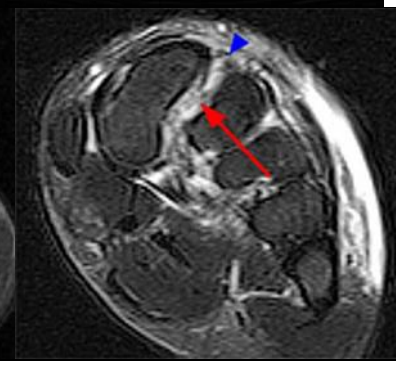
No signs of decreased arch height (double-sided arrow between black lines)

The plantar surface of C1 is superior to the plantar surface of the M5 base .

MRI:

Disruption of the dorsal, interosseous, and plantar components of the Lisfranc ligament complex (arrows).





E- Dancer Fracture

Secondary ossification center = Apophysis	Avulsion fracture at insertion of lateral cord of plantar fascia.	Avulsion fracture at insertion of peroneus brevis tendon	Jones Stress fracture 1.5 cm to 2 cm distal to the tuberosity

F- Os Naviculare

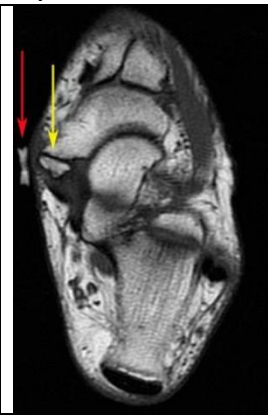
Geist classification: 3 main types of accessory navicular bones:

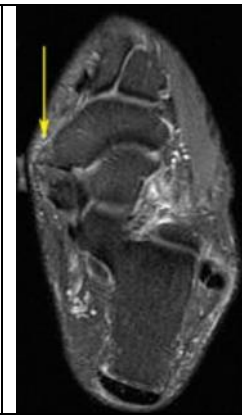
Type I: 4-6 mm ossicle, (true sesamoid), within substance of tibialis posterior

Type II: 1-3 mm triangular or heart shaped ossicle united to navicular via a synchondrosis

Type III: cornuate accessory navicular fused to main navicular via bony bridge

- An accessory navicular bone is a common congenital anomaly caused by aberrant ossification and is usually asymptomatic.
- Type II: the accessory and native navicular are united by a synchondrosis, accounts for the vast majority of symptomatic cases.
- Marrow edema within the accessory navicular bone and native navicular, (yellow arrow) indicative of chronic stress





G- Os Intermetatarseum

- Os intermetatarseum is present in approximately 1.2%–10% of feet. It is situated dorsally between the bases of metatarsals I and II.
- Os intermetatarseum is usually asymptomatic, but it can fracture or be associated with a varus deformity of metatarsal I and resulting hallux valgus.
- Os intermetatarseum may infrequently cause dorsal midfoot pain from compression of the medial branch of the deep peroneal nerve.

IV- Congenital Feet Abnormalities

A. Clubfoot (Talipes Equinovarus)

B. Rocker Deformity (Overcorrected Clubfoot)

C. Flatfoot

D. Metatarsus Varus and Adductus

E. Pes Cavus.

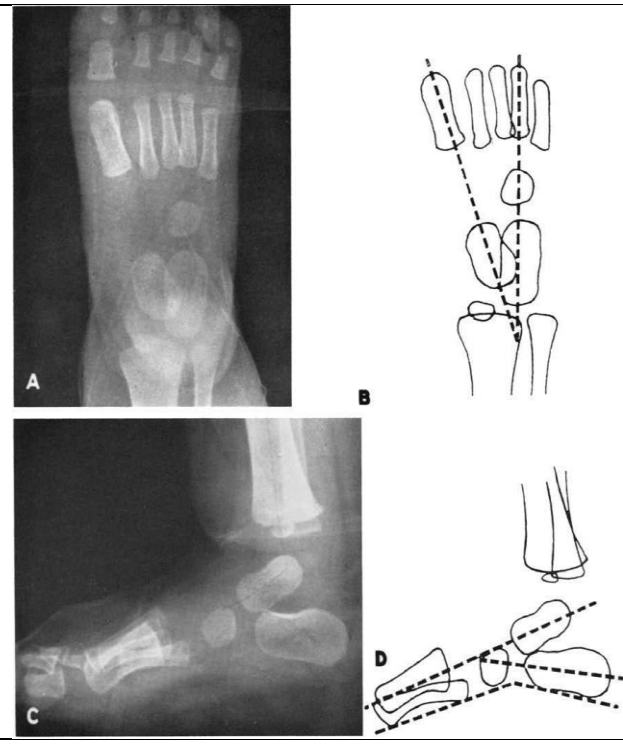
❖ Normal Foot:

AP

1) **AP Talo-calcaneal angle = 20 - 40°.**
2) The line through the mid-talus points to the head of the 1st metatarsal.
3) The line through the mid-calcaneus points to the head of the 4th metatarsal.
4) Lines of metatarsal shafts are very nearly parallel.

Lateral

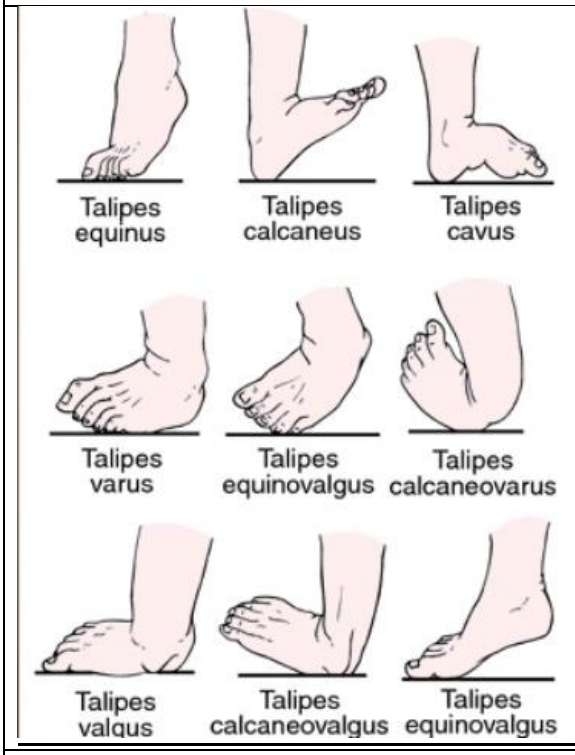
1) **Lateral talo-calacneal angle = 35-50°**
2) The mid-talar line and the line through the shaft of the 1st metatarsal coincide.
3) An obtuse angle is formed by the line through the inferior cortex of the calcaneus and inferior cortex of the 5th metatarsal.

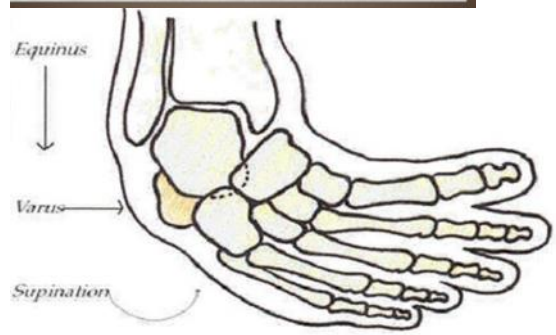


A. Talipes Equinovarus = Club Foot:

3 abnormalities:

- Adduction and varus deformity of the forefoot (Metatarsus adductus)
- Equinus = Plantar flexion of the hind foot.
- Varus = Adduction + Inversion of the hind foot.



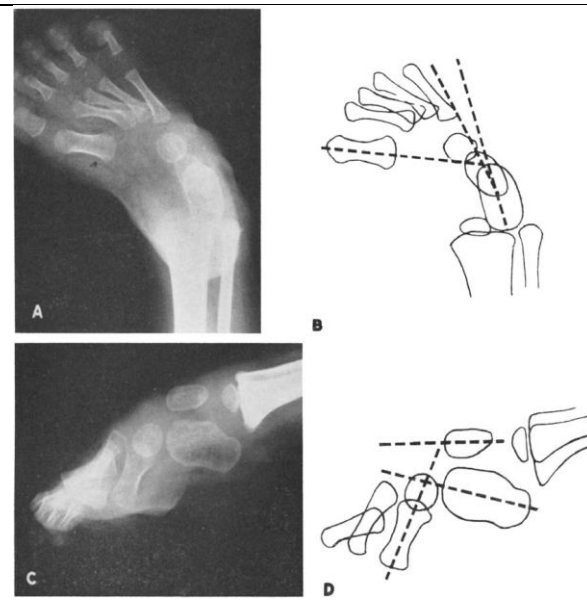


AP:

1) **AP talo-calcaneal angle <20°**
2) Mid-talar line points lateral to 1st metatarsal.
3) Mid-calcaneal line points lateral to 4th metatarsal.
4) Mid-talar line and the line through the shaft of the 1st metatarsal now form an angle.
5) Loss of parallelism of metatarsals, with convergence posteriorly.

Lateral

1) **Lateral talo-calcaneal angle <35°**
2) Mid-talar line and line through the shaft of the 1st metatarsal form an obtuse angle.
3) Mid-talar and mid -calcaneal lines approach parallelism.



B. Rocker Deformity

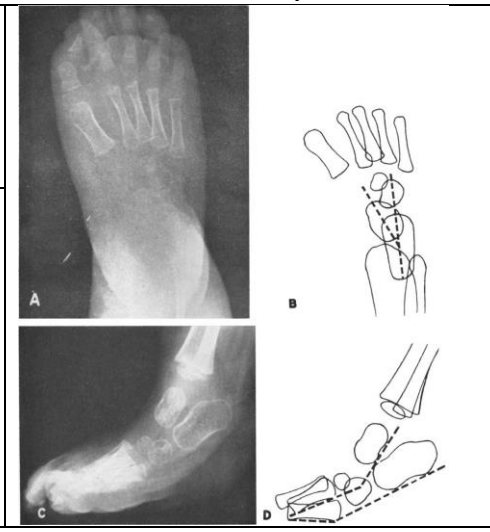
In correction of the equinus of a clubfoot, the longitudinal arch in the mid-talar joint is apt to "break," causing the characteristic "rocker" deformity.

AP

1) The angle between the calcaneus and talus is less than average.
2) The forefoot mayor may not be normal

Lateral

1) Reverse angle between inferior cortex of calcaneus and 5th metatarsal.
2) Reverse angle between inferior cortex of talus and 1st metatarsal in severe cases.



C. Pes planus = Flat foot

Loss of the medial longitudinal arch and can be either rigid or flexible.
There are several conditions associated with pes planus:

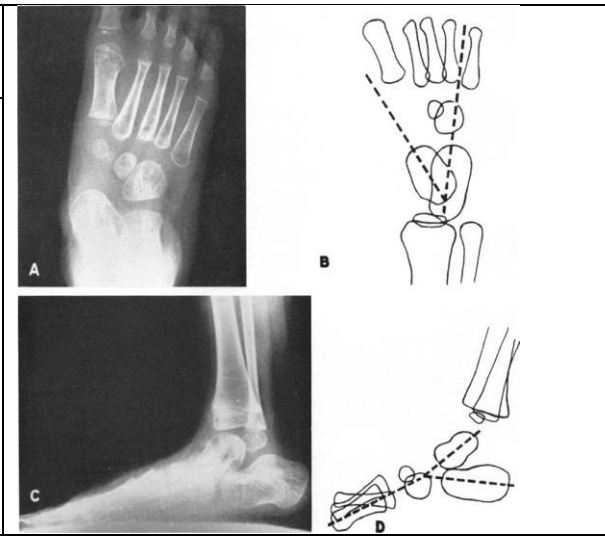
- Tarsal coalition
- Tibialis posterior tendon dysfunction
- Connective tissue disorders:
  - Marfan syndrome
  - Ehlers-Danlos syndrome

AP:

1) Increased talocalcaneal angle.

Lateral

1) The line of the 1st metatarsal makes an angle instead of coinciding with the mid-talar line.
2) Frequently there is an increased talocalcaneal angle.



D. Metatarsus Varus and Adductus

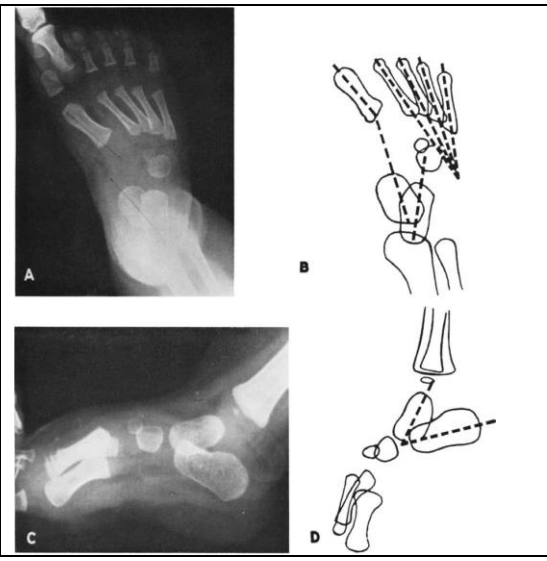
- Forefoot adduction, as in clubfoot, but the heel is in the valgus position.
- A milder form of this disorder, with forefoot adduction only, is referred to as "metatarsus adductus

AP:

1) **There is an increased angle between the mid- talar line and the line of the shaft of the 1st metatarsal.**
2) The lines of the metatarsals converge posteriorly.
3) The mid-calcaneal line runs lateral to the normal position

Lateral

1) The angle between the mid- calcaneal and mid-talar line may increase.

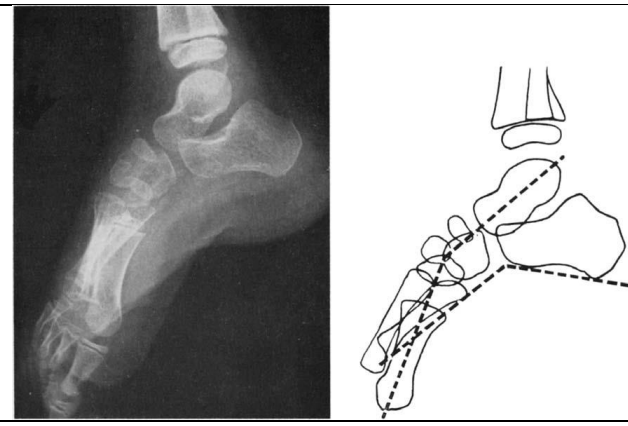


E. Pes Cavus

- This is a hollow foot characterized by elevation of the longitudinal arch and depression of the metatarsal arch

Lateral

1) Increased angle between the line through the inferior cortex of the calcaneus and inferior cortex of the 5th metatarsal.
2) There is now an angle between the mid-talar line and the line through the shaft of the 1st metatarsal.



Adult Flat Foot (Pes Planus)

1) Talonavicular Coverage Angle

- A measurement that is quite useful for evaluating pes planus on AP views is lateral subluxation of the navicular on the talus, or talonavicular uncoverage
- This is an indication of forefoot abduction, one of the three components of flatfoot.
- This measurement is taken off a weight-bearing AP (dorsolateral view).
- This angle represents the degree of shift of the navicular on the talus.
- Two lines are drawn, one connecting the edges of the articular surface of the talus, and one connecting the edges of the articular surface of the navicular.
- The angle formed by these two lines is the talonavicular coverage angle (Fig a).
- An angle > 7^{o} indicates lateral talar subluxation. (Fig b)

Normal and Abnormal Talonavicular Angle

a. Normal talonavicular coverage angle. The angle between the articular surfaces of the talus and the navicular is less that 7 degrees.

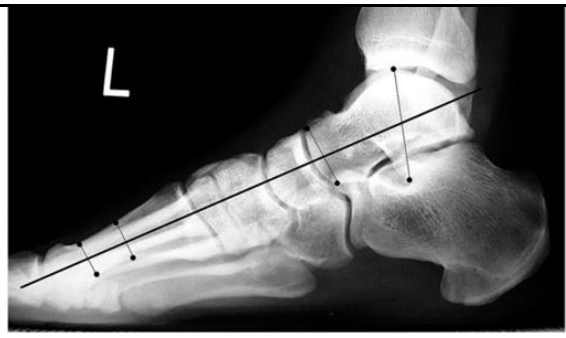
b. Talonavicular uncoverage indicating pes planus.

2) Lateral talar - 1st metatarsal angle (Meary's angle)

- This is an angle formed between:
- The long axis of the talus and first metatarsal on a weight-bearing lateral view.
- This line is used as a measurement of collapse of the longitudinal arch.
- Collapse may occur at the talonavicular joint, naviculo-cuneiform, or cuneiform-metatarsal joints.

In the normal weight-bearing foot, the midline axis of the talus is in line with the midline axis of the first metatarsal.

- An angle > 4° convex downward is considered pes planus
- An angle of 15° - 30° considered moderate
- An angle > 30° severe
- An angle > 4° convex upward is considered a pes cavus



a. Normal Meary's angle. The long axis of the talus intersects that of the first metatarsal.

b. The long axis of the talus is angled plantarward in relation to the first metatarsal, consistent with pes planus.

3) Calcaneal Pitch

The angle made between:

- A line drawn from the plantar-most surface of the calcaneus to the inferior border of the distal articular surface.
- A line drawn from the plantar surface of the calcaneus to the inferior surface of the 5th metatarsal head

Normal calcaneal pitch = 18 to 20°

A decreased calcaneal pitch is consistent with pes planus.

a. Normal calcaneal pitch.

b. Decreased calcaneal pitch indicating pes planus.